Nov. 15, 1966 R. E. BENWAY 3,286,113

CATHODE RAY TUBE

Filed Nov. 20, 1961

Fig. 1.

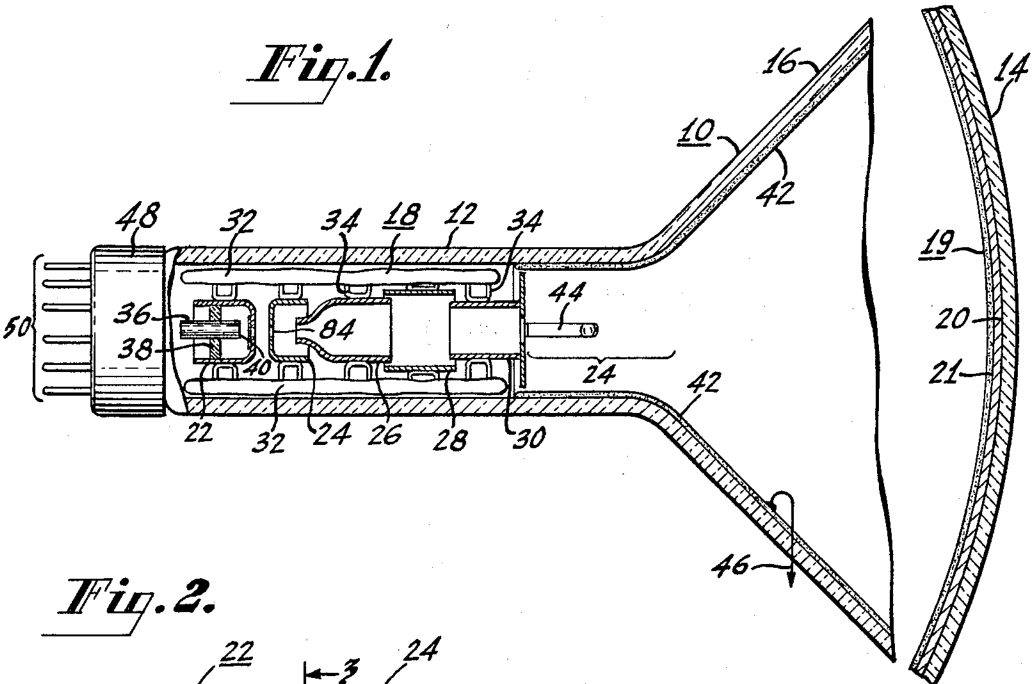
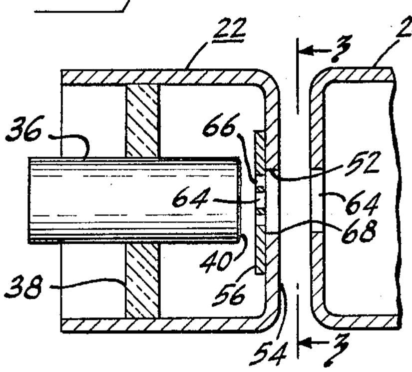


Fig. 2.



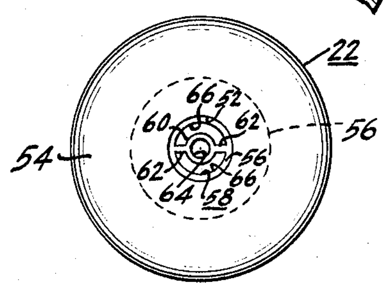


Fig. 3.

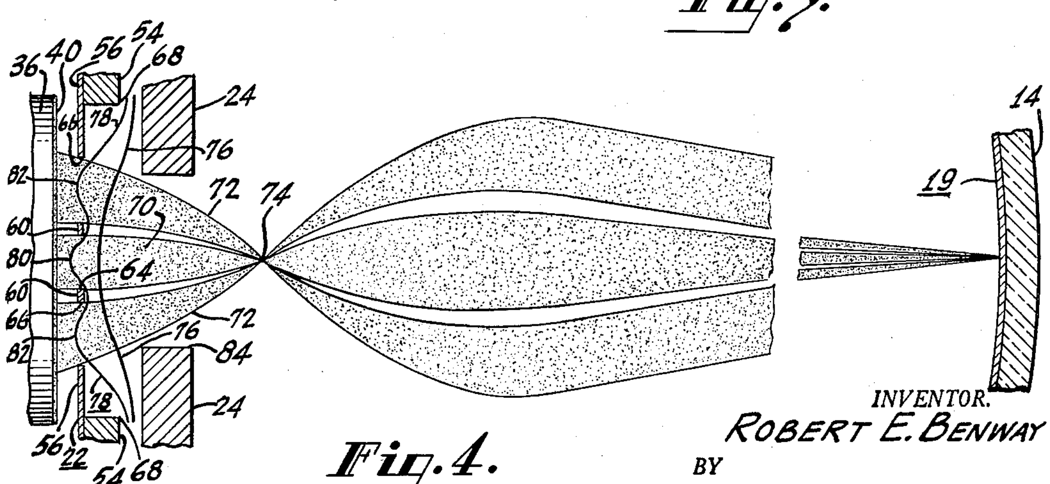


Fig. 4.

INVENTOR.
ROBERT E. BENWAY
BY
William A. Zalesak
ATTORNEY

United States Patent Office

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CATHODE RAY TUBE

Robert E. Benway, Marion, Ind., assignor to Radio Corporation of America, a corporation of Delaware

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8 Claims. (Cl. 313—82)

This invention relates to cathode ray tubes and particularly to an electron gun therefor having relatively high drive-sensitivity.

In many cathode ray tube applications, such as portable television receivers, it is desirable that the electron gun of the cathode ray picture tube have high (good) drive-sensitivity, i.e., that a small change of signal voltage between the cathode and the control grid of the picture tube effect a relatively large change in beam current intensity. Conventional electron guns of the type including a control electrode having a transverse plate with a circular beam-forming aperture therein do not exhibit the desired degree of beam control sensitivity.

Various schemes of the prior art have been proposed for the purpose of obtaining good drive sensitivity. Among there are the provision of electron guns having control electrodes with apertures whose areas are effectively subdivided into smaller elemental areas. Examples of the subdivided electrode apertures of the prior art are those having inwardly projecting tangs and those with crossed wires or meshes overlying a circular beam-forming aperture. The theory of these proposals is that a greater ratio of aperture boundary (electrode edge around aperture subdivisions) to total aperture area is provided, which in turn provides greater sensitivity of beam intensity control. While this theory is sound, most prior art approaches along these lines have been fraught with the problem of harmful beam breakup, which is due to the subdivision of the aperture area by the tangs, cross wires, meshes, or the like, and which is difficult, if not impossible, to satisfactorily focus to a desired single small spot on the phosphor screen. As a result, poor resolution is obtained.

In electron guns using control electrodes with subdivided apertures, attempts have been made to prevent beam breakup by spacing the control electrode extremely close to the cathode. This, however, presents a problem of fabrication due to the close spacing tolerances required.

It is therefore an object of this invention to provide a new and improved cathode ray tube having an electron gun of the subdivided-control-electrode-aperture type which has very high sensitivity and which at the same time is not fraught with problems of beam breakup or close spacing tolerances.

Briefly, according to features of this invention, a cathode ray tube includes an electron gun having a subdivided control electrode aperture which preferably includes a central circular aperture surrounded by an annular aperture concentric therewith. In operation of the tube, the electron streams passing through the different aperture subdivisions are individually converged to a common or coincident crossover at a point on the longitudinal axis of the gun. This cross over is imaged as a single small spot on the phosphor screen.

In the drawings:

FIG. 1 is a side elevation view partly in section and with parts each broken away of a cathode ray tube according to the invention;

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FIGS. 2 and 3 are enlarged longitudinal section and end plane views, respectively, of a portion of the tube of FIG. 1; and

FIG. 4 is a more greatly enlarged section of a portion of the tube of FIG. 1 illustrating the electron optics thereof.

Referring to FIG. 1, a cathode ray tube **10** includes an envelope comprising a neck section **12**, a faceplate **14**, and an interconnecting funnel section **16**. An electron gun **18** in the neck **12** is adapted to project an electron beam onto a target in the form of a luminescent screen **19** on the faceplate **14**. The screen **19** may be of any suitable type such as one comprising a layer **20** of phosphor material on the faceplate with a superimposed film **21** of evaporated aluminum thereupon.

The electron gun **18** comprises a plurality of coaxial, tubular, centrally-apertured electrodes including a control electrode cup **22**, a screen electrode cup **24**, and a focussing system including a first anode **26**, a focussing ring **28**, and a second anode **30**. These electrodes are mounted in coaxial spaced relationship along a pair of insulator rods **32** by U-shaped mounting studs **34** which are fixed to the electrodes and embedded in the insulator rods. A tubular cathode **36** is mounted in a centrally apertured insulator disk **38** which is in turn fixed within the control electrode cup **22**. The cathode **36** is closed at one end and coated with suitable materials to provide a planar electron emissive surface **40**.

A conductive coating **42** is provided on the internal surface of the funnel **16** and is connected to the luminescent screen **19** and to the second anode **30** through a plurality of spring snubbers **44** attached to the second anode. A high voltage contact terminal indicated schematically by the arrow **46** is provided for applying a suitable voltage to the coating **42**, the anodes **26** and **30**, and the phosphor screen **19**.

The neck **12** is closed at its free end with a stem structure **48** which includes a plurality of lead-in conductors **50** for applying suitable voltages to electrodes of the electron gun **18**.

In FIGS. 2 and 3, the control electrode cup **22** is shown to have an aperture **52** in its planar end wall **54**. A thin flat metal plate **56** is fixed to the end wall **54** inside the control electrode cup **22** and overlies the cup aperture **52**. The plate **56** is provided with a circular aperture **58** coaxial with the cup aperture **52**. A conductive ring **60** having a diameter smaller than the plate aperture **58** is concentrically mounted in the aperture **58** by a plurality of support rods **62**. By virtue of the ring **60**, the plate aperture **58** is effectively subdivided so as to form a small central circular aperture **64** and a surrounding, substantially complete annular aperture **66**. Although the annular aperture **66** is in fact itself subdivided by virtue of the support rods **62** into two approximately half-annular areas, for the purpose of brevity and clarity, it will herein simply be referred to as an annular aperture.

The circular aperture **64** and the annular aperture **66** of the plate **56** serve as the beam forming and control aperture of the control electrode **22** and as such are disposed opposite the emissive surface **40** of the cathode.

The cup aperture **52** in the end wall **54** of the control electrode cup is of a diameter larger than the outside diameter of the annular aperture **66**. As a result, that portion of the end wall **54** forming the circular boundary of the cup aperture **52** provides a shoulder **68** concen-

purpose of shaping a beam-converging, electron-accelerating field as hereinafter described.
trically surrounding the beam control aperture 58 for the

In contrast with prior art electron guns having subdivided control electrode apertures, electron gun construction and operation according to this invention results in each individual electron stream which passes through each subdivision of the control electrode aperture being individually converged to a common or coincident crossover. Such a convergence permits imaging of a finite spot by the focussing field onto the luminescent screen, thus in turn affording good image resolution.

Referring to FIG. 4, in operation of the electron gun **18**, electrons are emited from the emissive surface **40** of the cathode **36** and drawn through the control electrode beam-forming apertures **64** and **66** to provide a solid, central circular stream **70** and a surrounding annular stream **72**. The electron streams **70** and **72** are individually converged to a common first crossover **74** at a point on the longitudinal axis of the gun by convergent electrostatic fields established in the regions between the control and screen electrodes **22** and **24**. The crossover **74** is then imaged by focusing fields established by the focusing system including electrodes **26**, **28**, and **30** onto the luminescent screen **19**. Such operation of the electron gun **18** is achieved by properly relating the electrode dimensions and spacings and applying suitable voltages to the electrodes as hereinafter more fully described.

Convergence of the circular electron stream **70** to the crossover **74** as referred to in the preceding paragraph involves formation of the circular stream into a somewhat conical shape between the cathode **36** and the crossover **74**. The apex of the electron cone thereof occurs at and forms the crossover. Convergence of the annular electron stream **72** to the cross-over **74** as referred to in the preceding paragraph involves both a thinning down of the thickness of the annular wall of the electron stream **72** and a convergence of this annular wall to the crossover point **74** of the circular stream **70**.

From the crossover **74**, the electrons of both the circular stream **70** and the annular stream **72** proceed toward the luminescent screen **19** in divergent paths until they encounter the focusing field of the electrodes **26**, **28**, and **30**. This focusing field then reconverges the electron streams **70** and **72** to a point, or small spot, on the luminescent screen **19**. This focusing action may be described as an imaging of the common crossover **74** on the luminescent screen.

In FIG. 4 an ideal point-crossover **74** is illustrated for the purpose of more clearly explaining the operation of the invention. However, in practice, as is true with any electron stream crossover, the crossover **74** actually has a finite length along the gun axis and a finite diameter. As is well known in the art, realization of an ideal point-crossover in evacuated devices is never fully obtained due to space charge mutual repulsion forces between the electrons of the stream.

The electron optics of the gun **18** produce the desired coincident crossover **74** of both the circular and annular electron streams **70** and **72** in a way illustrated in FIG. 4. Suitable voltages are applied to the electrodes of the gun **18** to provide an accelerating electrostatic field between the control and screen electrodes **22** and **24**. Two equipotential lines **76** and **78** of this accelerating field are shown for the purpose of more clearly explaining the operation of the gun **18**.

As shown by the equipotential line **78**, the accelerating field dips into the central aperture **64** to provide a relatively strong convergent field portion **80** localized opposite the central circular aperture **64**. The convergent field portion **80** acts to focus the circular electron stream **70** to the first crossover **74** as hereinbefore described. Similarly, the accelerating field dips into the annular aperture **66** to provide a relatively strong convergent field portion **82** localized opposite the annular aperture **66**. The annular convergent field portion **82** serves to focus the annular electron stream **72** so that the thickness of the wall of the annular stream is thinned down as it proceeds away from the cathode emissive surface **40**.

Were the accelerating field between the control and screen electrodes **22** and **24** planar, i.e., without concave curvature as is illustrated by the line **76**, the effect of the convergent field portion **82** would be to simply focus or thin the wall of the annular electron stream **72** to an annular crossover with the diameter of the annular stream **72** remaining the same. If such were the case (which it is not), the wall of the annular stream **72** would not be converged to a point crossover but rather would proceed along a cylindrical path generally perpendicular to the cathode emissive surface **40**. However, the accelerating field between the control and screen electrodes **22** and **24** is not planar but rather is concave toward the screen electrode **24** so that the annular convergent field portion **82** is tilted toward the central axis of the gun **18** to form the annular convergent field portion **82** into a somewhat frusto-conical shape with the large end of the frustum adjacent to the control electrode **22**. The central convergent field portion **64** is substantially planar with respect to the central axis of the gun, in order to focus the central beam without deflecting it.

The shoulder **68** on the control electrode **22** is that portion of the electrode structure of the gun **18** which primarily produces the concavity of the accelerating field. The shoulder **68** causes the accelerating field as illustrated by the equipotential lines **76** and **78** to be spaced further away from the plane of the apertured control electrode plate **56** than is the central portion of the accelerating field, thus providing the desired concavity.

Other means, such as a concave shaping of the apertured end walls of the control and screen electrodes **22** and **24**, could be used to produce the desired concavity of the accelerating field. The use of the shoulder **68** is preferred because of its simplicity and adaptability as to size selection for selection of the degree of concavity as hereinafter described.

In order to obtain optimum operational characteristics of the electron gun **18**, the beam control apertures **64** and **66** in the control electrode **22** are of such relative size as to provide simultaneous cutoff of their respective electron streams **70** and **72**. In the case of each of these apertures, as its size is decreased, cutoff of its electron stream is obtained with a smaller voltage difference between the cathode and control electrode. Cutoff of the two electron streams **70** and **72** can also be selected by selecting the size of the aperture **84** in the screen electrode **24**. As screen electrode aperture **84** is increased in diameter, the voltage difference between the cathode and control electrode necessary to produce cutoff is increased. However, varying the size of the screen electrode aperture **84** varies the cutoff voltages of the circular and annular electron streams **70** and **72** at different rates. Thus, size selection of screen aperture **84** provides a way of contributing to equalization of cutoff for the two electron streams **70** and **72**.

Varying the size of the beam control apertures **64** and **66** also affects the strengths of the convergent field portions represented by field lines **80** and **82**, which determine the distance from the cathode surface **40** of the crossover **74**. Decreasing the size of one of these apertures increases the strength of its convergent field portion **80** or **82**, which in turn moves the crossover **74** of its electron stream **70** and **72** closer to the control electrode **22**. Therefore, in designing the electron gun **18**, the beam control apertures **64** and **66** and the screen electrode aperture **84** are made of a selected size to obtain both simultaneous cutoff of the circular and annular electron streams **70** and **72** and a crossover of these streams at the same distance from the cathode surface **40**.

In order to obtain a concidence of the crossovers of both the circular and annular electron streams **70** and **72**, the concavity of the accelerating field is made to be of a selected magnitude. The greater the concavity of the accelerating field, i.e., the smaller its radius of curvature, the greater is its strength and the closer the crossover **74** of the annular electron stream is to the control electrode **22**. Either an increase of the thickness of the end plate **54** to provide greater height to the shoulder **68** or a decrease of diameter of the cup aperture **52** to move the shoulder radially inward serves to increase the concavity, and thus the strength, of the accelerating field.

Adjustment of the degree of concavity of the accelerating field can also be obtained by varying the diameter of the aperture **84** in the screen electrode **24**.

The apertured control electrode plate **56** is made to have a thickness which will most easily permit obtaining of the desired electron optics. As its thickness is increased, other parameters remaining fixed, electrode spacings are affected. This in turn affects the strength of the convergent field portions **80** and **82** and consequently the location of the crossovers of the electron streams **70** and **72**. If the plate **56** is made too thick, the cutoff characteristic is degraded beyond a desired limit.

The width of the ring **60** dividing the control electrode aperture into its circular and annular parts is preferably made as small as practical so as to intercept as few electrons as possible and thus maximize the amount of cathode emission for any given drive voltage.

The preferred mode of operation of the gun **18** is in grounded grid drive with the cathode biased at cutoff and driven with a negative signal from cutoff to zero bias. The gun **18** can, however, be operated in other modes.

One embodiment of the invention successfully operated in the preferred mode, comprises an electron gun **18** of the general type used in a commercial 23AHP4 type television picture tube, but in which the control and screen electrodes are specially fabricated as follows:

	Mils
Thickness of control electrode end wall **54**	7
Thickness of control electrode apertured plate **56**	1
Thickness of apertured end wall of screen electrode **24**	10
Diameter of cup aperture **52**	60
Diameter of circular aperture **64**	10
Inside diameter of annular aperture **66**	15
Outside diameter of annular aperture **66**	40
Diameter of screen electrode aperture **84**	31
Spacing between cathode **36** and control electrode plate **56**	4
Spacing between control electrode wall **54** and screen electrode **24**	4

Suitable D.C. voltages for operating such a gun in the preferred mode are as follows:

Cathode **36**	volts	+28
Control electrode **22**	volts	0
Screen electrode **24**	volts	+50
Anodes **26** and **30** and luminescent screen **19**	kilovolts	+16
Focus ring **28** (as required to obtain proper focus)	volts	0 to +400

With the above noted structural dimensions and operating voltages, the gun **18** has a cutoff of only 28 volts and produces a zero bias current of 2200μ amps.

With slightly different structural dimensions in another embodiment of the invention a cutoff of, for example, only 20 volts and a zero bias current capability of about 1350μ amps may be obtained.

What is claimed is:

1. A cathode ray tube comprising a luminescent screen and an electron gun adapted to project an electron beam onto said screen, said gun comprising a plurality of electrodes aligned along a central axis, said electrodes including a cathode having a planar electron emitting portion, a control electrode including a planar portion having a subdivided beam control aperture of given diameter opposite said cathode portion, an electron accelerating electrode for accelerating electrons emitted from said cathode portion into separate streams passing through the subdivisions of said aperture, said accelerating electrode having a single aperture of given diameter spaced from and coaxial with said beam control aperture, means including a low potential field-forming electrode adjacent to said control electrode on the side thereof opposite from said cathode and having a single aperture of substantially greater diameter than said given diameters coaxial with said beam control aperture for creating between said control and accelerating electrodes a convergent electric field for individually converging and focusing each of said electron streams to a common crossover on said central axis, and means for converging and focusing said streams between said crossover and said screen to image said crossover on said screen.

2. A cathode ray tube as in claim **1**, wherein, said control electrode has a central circular aperture and a substantially annular aperture concentrically substantially surrounding said circular aperture.

3. In a cathode ray tube an electron gun including in aligned disposition a cathode, and control, accelerating, and focusing electrodes, said control electrode having opposite said cathode a central circular aperture and an annular aperture concentrically substantially surrounding said circular aperture, and means including an annular shoulder on said control electrode on the side thereof opposite from said cathode concentrically surrounding and spaced radially from said annular aperture for establishing a circular convergent field opposite said circular aperture and an annular convergent field opposite said annular aperture, said apertures being so sized as to have the same cutoff voltage, said convergent fields being so shaped and of such intensity as to converge the electron streams through their respective apertures to a common crossover point on the axis of said gun.

4. A cathode ray tube comprising a luminescent screen and an electron gun adapted to project an electron beam onto said screen, said gun including in aligned disposition a cathode, and control, accelerating, and focusing electrodes, said control electrode having opposite said cathode a central circular aperture and an annular aperture concentrically substantially surrounding said circular aperture, and means including an annular shoulder on said control electrode on the side thereof opposite from said cathode concentrically surrounding and spaced radially from said annular aperture for establishing an accelerating field between said control and accelerating electrodes opposite their apertures which is concave toward said accelerating electrode and which has a circular portion dipping into said circular aperture enforcing convergence of the electron stream passing therethrough to a point on the axis of said gun and an annular portion dipping into said annular aperture enforcing convergence of the electron stream passing therethrough, the strength of said annular convergent field portion and the curvature of concavity of said accelerating field being such as to converge said annular stream to said point, the relative dimensions of said circular and annular apertures being such that the beam cutoff voltage is substantially the same for each of said apertures.

5. A cathode ray tube as in claim **1**, wherein said control electrode comprises a relatively thick wall portion having an opening larger than said aperture, and a relatively thin plate containing said aperture mounted over said opening on the side towards said cathode, whereby the wall of said opening constitutes said shoulder.

6. A cathode ray tube as in claim **1**, wherein said field-forming electrode is in contact with said control electrode.

7. A cathode ray tube as in claim **1**, wherein the diameter of said accelerating electrode aperture is smaller than the diameter of said beam control aperture.

8. A cathode ray tube as in claim 1, wherein said common crossover is located between said accelerating electrode and said screen.

References Cited by the Examiner

UNITED STATES PATENTS

2,721,287	10/1955	Van Ormer	313—82 X
2,862,144	11/1958	McNaney	313—82.1 X

2,919,380	12/1959	Barnett	313—82.1 X
2,880,342	3/1959	Frenkel	313—82.1 X
2,971,118	2/1961	Burdick	313—82 X
2,975,315	3/1961	Szegho	313—251 X
2,988,658	6/1961	Skellett	313—82

HERMAN KARL SAALBACH, *Primary Examiner.*

ARTHUR GAUSS, *Examiner.*

S. CHATMON, Jr., *Assistant Examiner.*