June 3, 1969 SUSUMU YOSHIDA ET AL 3,448,316

CATHODE RAY TUBE

Filed Jan. 12, 1968 Sheet 1 of 3

FIG. 1.

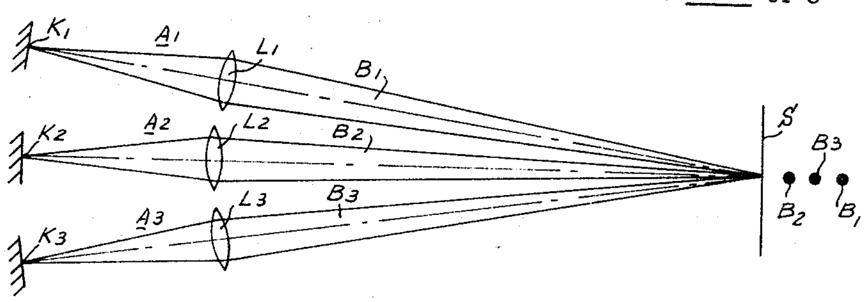


FIG. 2.

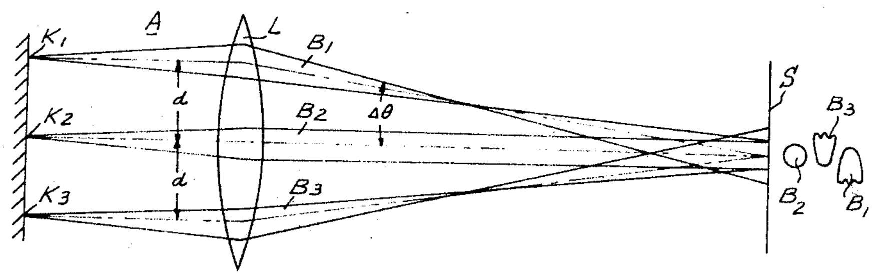


FIG. 3.

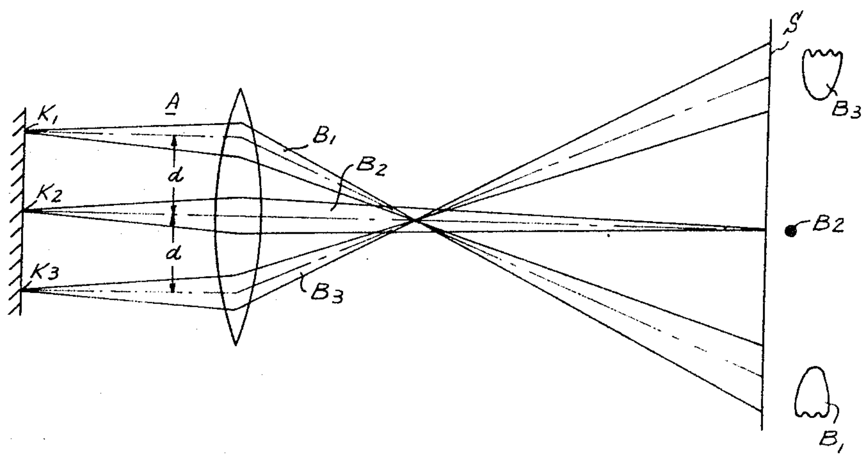
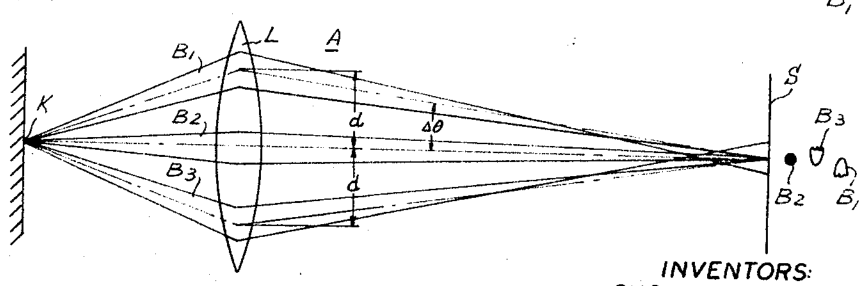


FIG. 4.



INVENTORS:
SUSUMU YOSHIDA
AKIO OHGOSHI
SENRI MIYAOKA
YOSHIHARU KATAGIRI

BY Lewis H. Eslinger

ATTORNEY

FIG. 5.

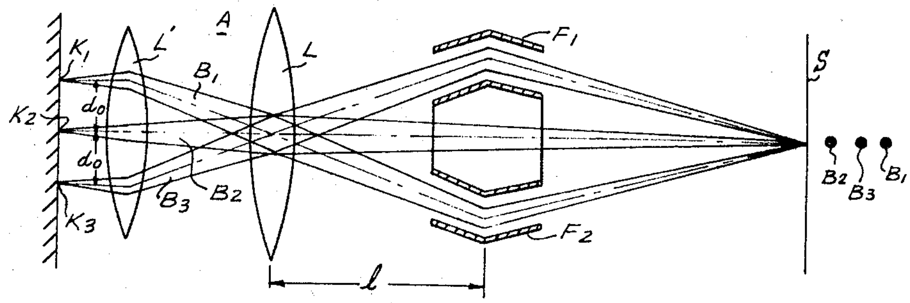


FIG. 6.

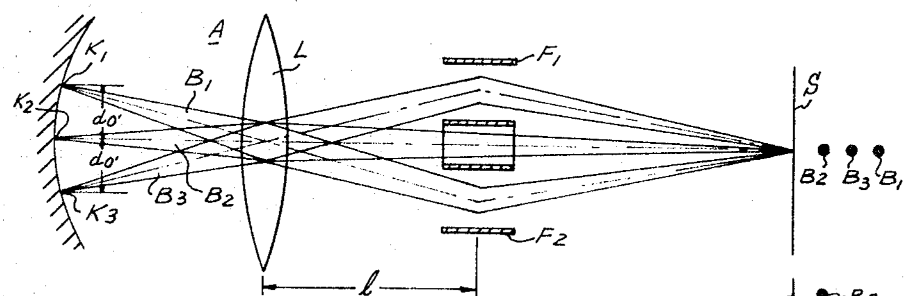


FIG. 7.

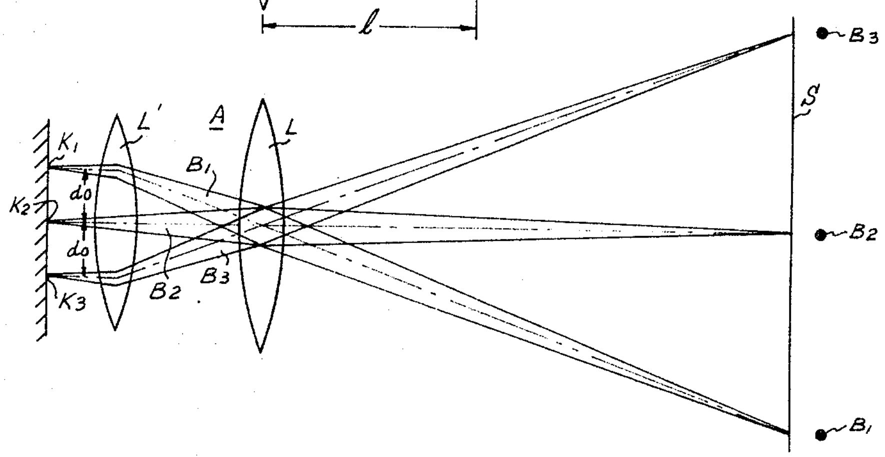
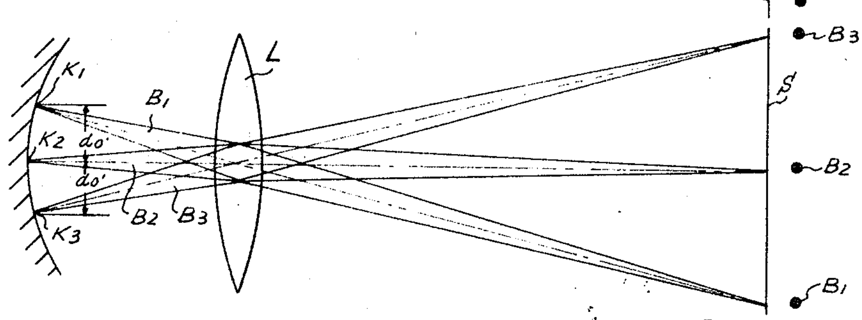


FIG. 8.



INVENTORS:
SUSUMU YOSHIDA
AKIO OHGOSHI
SENRI MIYAOKA
YOSHIHARU KATAGIRI
BY Lewis H. Eslinger
ATTORNEY

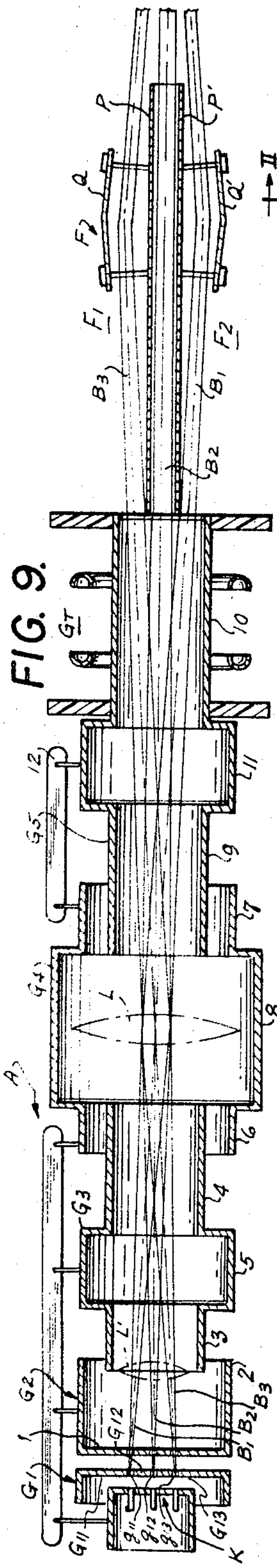


FIG. 9.

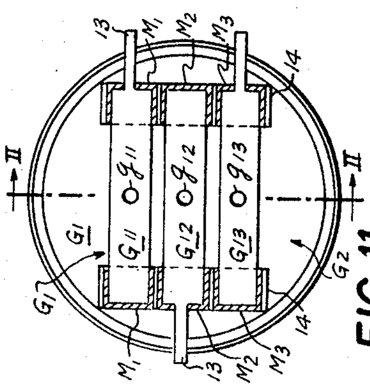


FIG. 11.

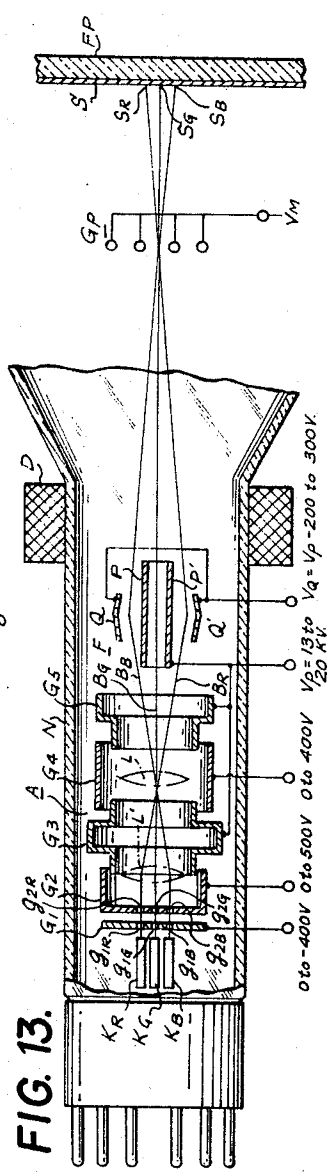


FIG. 13.

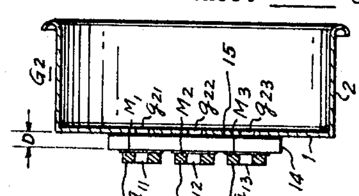


FIG. 12.

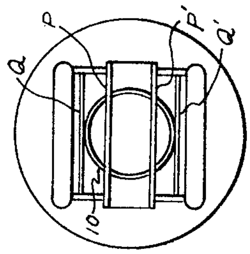


FIG. 10.

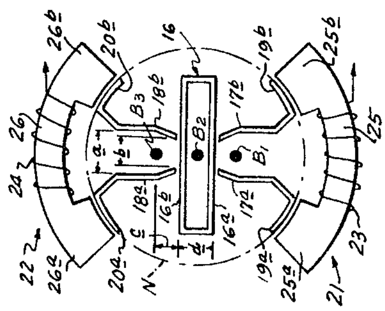


FIG. 14B.

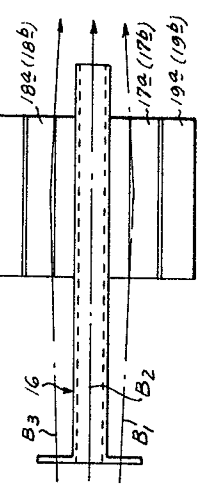


FIG. 14A.

INVENTORS:
SUSUMU YOSHIDA
AKIO OHGOSHI
SENRI MIYAOKA
YOSHIHARU KATAGIRI

BY

Lewis H. Eslinger

ATTORNEY

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CATHODE RAY TUBE

Susumu Yoshida and Akio Ohgoshi, Tokyo, Senri Miyaoka, Kanagawa-ken, and Yoshiharu Katagiri, Tokyo, Japan, assignors to Sony Corporation, Shinagawa-ku, Tokyo, Japan

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Int. Cl. H01j 29/46, 31/00
U.S. Cl. 313—69 33 Claims

ABSTRACT OF THE DISCLOSURE

A color picture tube or other cathode ray tube employing a plurality of electron beams includes a single electron gun having one or more cathodes emitting electrons formed into the plurality of beams which are made to converge or cross each other substantially at the optical center of an electrostatic focusing lens by which the beams are focused on the electron-receiving screen of the tube, whereby to avoid spherical aberration and/or coma. When the beams focused on the electron-receiving screen are all to converge at a common point on such screen, an electrostatic or magnetic deflection device acts on those beams which diverge after passing through the lens-like focusing system.

This invention generally relates to cathode ray tubes, and more particularly is directed to improvements in color cathode ray tubes of the type in which a single electron gun is provided for emitting a plurality of electron beams to produce a color picture, for example, as in color television receivers.

Existing color picture tubes are usually of the multi-gun type and include three independent electron guns emitting respective electron beams which are modulated by corresponding color signals and acted upon by a grid system so as to be focused on a collector or electron-receiving screen which may be simply a phosphor or luminescent screen or a phosphor screen with a perforated electrode or shadow mask in front thereof. The three electron guns have to be aligned with respect to each other so that the emitted electron beams converge at the electron-receiving screen. Such color picture tubes of the multi-gun type are disadvantageous in that it is difficult to obtain and maintain the precise alignment of the three electron guns required for the convergence of their beams on the electron-receiving screen and any misconvergence of the beams causes deterioration of the quality and resolution of the color picture that results. Further, when using three independent electron guns to produce the beams, the color picture tube is necessarily costly and, by reason of the space required for the three guns, the possible miniaturization of the tube is correspondingly limited.

In an attempt to avoid the above mentioned disadvantages and limitations of the existing color picture tubes of the multi-gun type, it has been proposed to provide a color picture tube of the single-gun, plural-beam type in which a single electron gun emits three beams from either three respective cathodes or a single cathode, and the three electron beams are passed through a lens-like focusing system, so as to converge at the electron-receiving screen. However, in the tubes of the single-gun,

plural-beam type heretofore proposed, no more than one of the electron beams passes through the lens-like focusing system at the optical axis of the latter, and the beams that pass through the focusing system at a distance from the optical axis are subject to coma and spherical aberration. By reason of such coma and spherical aberration and the consequent deterioration of the quality of the color picture that results, color picture tubes of the single-gun, plural-beam type have not enjoyed any wide-spread use.

Accordingly, it is an object of this invention to provide a cathode ray tube of the single-gun, plural-beam type which is free of the above mentioned disadvantages characteristic of tubes of that type as previously proposed, and which is particularly suited to serve as a color picture tube for producing color pictures of high resolution and brightness.

Another object of this invention is to provide a cathode ray tube, particularly a color picture tube, which is of the single-gun, plural-beam type and can be relatively easily manufactured even when miniaturized to a considerable degree.

Still another object of this invention is to provide a color picture tube of the single-gun, plural-beam type in which correction for convergence can easily be effected.

In accordance with an aspect of this invention, a cathode ray tube adapted for use as the picture tube of a color television receiver is provided with a single electron gun including a cathode structure emitting electrons which are formed, as by a grid structure, into a plurality of electron beams, and such beams are made to converge substantially at the optical center of a lens-like, electrostatic focusing means which is common to all the beams and focuses the beams on the electron-receiving screen, whereby the introduction of optical errors such as spherical aberration and/or coma is avoided.

In cases where the electron beams are emitted parallel to each other, the convergence of the beams at the optical center of the lens-like focusing means in accordance with this invention is effected by auxiliary electrostatic lens means located between the grid structure which forms the electron beams and the focusing means.

Further, when it is desired that the beams focused on the electron-receiving screen should be converged at a common point on the screen, the beams which diverge from the lens-like focusing means are acted upon by either electrostatic or magnetic deflection means located between the focusing means and the screen.

The above, and other objects, features and advantages of this invention, will become apparent from the following detailed description of illustrative embodiments which is to be read in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view illustrating the optical equivalent or analogy of a three electron gun system, as in a conventional color cathode ray tube;

FIGS. 2 and 3 are similar diagrammatic views of the optical equivalent or analogy of a single-gun, plural-beam system, as previously proposed;

FIG. 4 is a diagrammatic view of the optical equivalent or analogy of still another single-gun, plural-beam system as previously proposed;

FIG. 5 is a similar diagrammatic view showing the optical equivalent of an electron gun according to an embodiment of this invention;

FIG. 6 is a view similar to that of FIG. 5, but illustrating an electron gun according to a second embodiment of this invention;

FIGS. 7 and 8 are diagrammatic views of the optical equivalents of still other embodiments of this invention;

FIG. 9 is a schematic longitudinal sectional view of an electron gun in accordance with the embodiment of this invention represented by the optical analogy of FIG. 5;

FIG. 10 is an end view of the gun shown on FIG. 9;

FIG. 11 is an enlarged elevational view showing details of first and second grids of the electron gun according the embodiment of this invention shown in FIG. 9;

FIG. 12 is a sectional view taken along the line II—II on FIG. 11;

FIG. 13 is a schematic, axial sectional view of a chromatron type color cathode ray tube embodying the present invention; and

FIGS. 14A and 14B are respectively a plan view and an end view of magnetic deflection means which can be used for converging the electron beams in a cathode ray tube according to this invention.

In order that the electron gun for a cathode ray tube according to the present invention may be better understood, the principles and features of conventional electron guns employing the triple-gun system and the single-gun, triple-beam system, respectively, will first be described in detail with reference to FIGS. 1 to 4.

FIG. 1 shows the optical equivalent or analogy of a conventional system employing three independent electron guns A_1, A_2 and A_3. In such system, there are provided three independent beam generating sources K_1, K_2 and K_3 emitting three beams B_1, B_2 and B_3, respectively, which are focused onto an electron-receiving or phosphor screen S through separate main lens systems L_1, L_2 and L_3, respectively. With such an arrangement, however, the three independent electron guns A_1, A_2 and A_3 which need to be accommodated in the neck portion of the tube envelope obviously restrict the extent to which the diameter of the neck portion can be reduced. Further, if the effective diameter of each electron gun is limited so as to permit the accommodation of the three guns in a neck portion of reasonable diameter, the outer portions of each beam necessarily pass through parts of the respective main lens system L_1, L_2 or L_3 which are spaced substantially from the optical axis thereof whereby spherical aberrration results with the consequence that each beam impinges on the screen S as a relatively large spot, as indicated at the right-hand side of FIG. 1, and high resolution cannot be obtained. It will also be apparent that, in using three independent electron guns, it is inherent that difficulties will be encountered in obtaining and maintaining the precise alignment of the guns necessary for converging the beams B_1, B_2 and B_3 at screen S.

FIG. 2 shows the optical equivalent of a conventional single-gun, triple-beam system in which the single electron gun A includes equivalent beam generating sources K_1, K_2 and K_3 spaced from each other by the distances d and from which three beams B_1, B_2 and B_3 are emitted in parallel to each other so as to pass through the common main lens system L and be converged by the latter on the screen S.

Whether the electron gun system of a color cathode ray tube is of the triple-gun type (FIG. 1) or of the single-gun triple-beam type (FIG. 2), it is necessary that the three electron beams be converged at an angle of $\Delta\theta$ between the center beam (B_2 in the drawing) and each of the other beams so that the three beams cross or intersect each other at the position of a mask or grid provided in front of the phosphor or luminescent screen and are thus made to land or impinge on respective color dots or stripes which are adapted to produce different color light rays.

In order to meet the foregoing requirements with respect to the angle $\Delta\theta$ in the single-gun, triple-beam system, it is essential that the three beams B_1, B_2 and B_3 be spaced apart from each other by the substantial dis-

tance d when they pass through the main lens L. Thus, beams B_1 and B_3 pass through portions of lens L which are spaced substantially from the axis of the lens L by the distance d, so that the beam spots on the screen S are deformed, as shown at the right-hand side of FIG. 2, due to coma as well as to spherical aberration. In the case shown on FIG. 2, the focusing of the beams is adjusted to achieve perfect convergence at the screen S. This inevitably decreases the focusing effect imparted to each beam. Thus, the beams are under-focused so that the resulting beam spots are enlarged, as is apparent at the right-hand side of FIG. 2. On the other hand, if the focusing voltage is adjusted to sharply focus beam B_2 on screen S, this causes the beam spots B_1, B_2 and B_3 on the screen S to be scattered, as shown on FIG. 3. Therefore, special means have to be provided to converge or superimpose the beam spots which are thus scattered. However even in that case the beam spots B_1 and B_3 are deformed due to coma, as shown on the right-hand side of FIG. 3.

In an attempt to satisfy the contradictory conditions of focusing the three beams on screen S and of converging the three beams at the screen, it is conceivable that the three beams B_1, B_2 and B_3 could be emitted from a beam generating source K in three different or angularly displaced directions so as to be spaced apart from each other a distance d at the position of the main lens L, as illustrated on FIG. 4. Although the above two conditions can thus be simultaneously satisfied with only negligible spherical aberration, nevertheless the side beam spots B_1 and B_3 are blurred due to the coma, as shown at the right-hand side of FIG. 4, since the side beams pass through the main lens L at positions spaced from the axis of the lens by the distance d.

It will be seen from the above that cathode ray tubes employing the single-gun, triple-beam system as previously devised or proposed fail to satisfactorily meet the three-beam spot focusing condition and the three-beam spot converging condition and therefore have not been put to practical use as yet.

In the following detailed description of illustrative embodiments of single-gun, plural-beam systems according to this invention, particular reference is made to the use thereof in color picture tubes, but it is to be understood that the described single-gun, plural-beam systems according to this invention can be applied to any other cathode ray tubes in which plural electron beams are required.

In the system according to this invention, as illustrated by its optical equivalent or analogy on FIG. 5, a single electron gun A includes equivalent beam generating sources K_1, K_2 and K_3 which are located on a straight line in a plane substantially perpendicular to the axis of the electron gun and spaced apart from each other by a distance d_0. These beam generating sources K_1, K_2 and K_3 emit three electron beams B_1, B_2 and B_3, respectively, which are refracted by means of a common auxiliary lens L′ so as to be converged substantially at the optical center of a main lens L. Thus, the three beams B_1, B_2 and B_3 are made to cross each other at the optical center of the main lens L and then emerge from the lens L in divergent directions. Subsequently, the beams B_1 and B_3 which diverge from the optical axis and from the beam B_2 lying on such axis, are deflected toward the center beam B_2 by means of convergence deflectors F_1 and F_2 provided between the electron-receiving screen S and the main lens L and spaced from the latter by a distance l, so that the three beam spots B_1, B_2 and B_3 on the screen are converged or superimposed on each other.

With the arrangement of FIG. 5, therefore, very small beam spots can be obtained since all three beams B_1, B_2 and B_3 pass through the center of main lens L, and thus the focused beam spots are prevented from being blurred due to the coma and spherical aberration. Consequently, a picture with a high resolution can be produced. Furthermore, utilization of the deflectors F_1 and F_2 advantageously facilitates the dynamic convergence correction with respect to the three beams. Although FIG. 5 represents the deflectors as being of the electrostatic type, they may be of the magnetic type as hereinafter described in detail.

FIG. 6 shows the optical equivalent of a cathode ray tube according to a second embodiment of this invention in which a single electron gun A includes beam generating sources K_1, K_2 and K_3 arranged on an arcuate surface having its center at the optical center of a main lens L, and being spaced from each other by the straight distance d_0'. In this embodiment, the auxiliary lens L' of FIG. 5 is omitted, as the arrangement of the sources K_1, K_2 and K_3 on the described arcuate surface causes the three beams B_1, B_2 and B_3 to cross each other at the optical center of the main lens L, as in the embodiment shown on FIG. 5. Deflectors F_1 and F_2 are provided along the paths of the two beams B_1 and B_3 which cross each other within lens L and then follow divering emergent paths, and such deflectors cause the beams B_1 and B_3 to converge and intersect the beam B_2 at the screen S. Thus, good resolution of the picture can be obtained in the same manner as described above in connection with FIG. 5.

Although the beam generating sources K_1, K_2 and K_3 in FIGS. 5 and 6 are spaced apart from each other by a distance d_0 or $d_{0'}$, along a straight line, it is possible to arrange these beam generating sources at the vertices of an equilateral triangle, in which case deflectors, as at F_1 and F_2, may be provided for each of the three beams or for only two of them. Preferably, the beam generating sources are arranged along a straight line, as shown. The reasons are that, with such preferred arrangement, the effective distance over which the beams are spaced apart from the optical axis can be minimized, the dynamic convergence correction can be easily effected, and asymmetrical convergence of the three beam spots on the screen can be prevented.

In the embodiments of this invention described above with reference to FIGS. 5 and 6, the three beams B_1, B_2 and B_3 are made to converge at the screen S. However, it is also possible to omit the deflectors F_1 and F_2 so that the three beams B_1, B_2 and B_3 cross each other at the optical center of the main lens L and thereafter continue along divergent paths so as to strike the screen at three different positions spaced from each other by a predetermined distance, as shown on FIGS. 7 and 8 which correspond to FIGS. 5 and 6, respectively. With the arrangements of FIGS. 7 and 8 the three beam spots on the phosphor screen are not affected by the spherical aberration and coma of the main lens, so that such beam spots need not be deformed as shown on FIGS. 2 to 4. When the beam spots are spaced apart on screen S, time differences corresponding to the three beam spot positions are imparted to the video signals modulating the three beams, thereby achieving correspondence between the three pictures produced on the phosphor screen by the three beams.

A particular example of the structure of an electron gun A corresponding to the optical analogy of FIG. 5 will now be described with reference to FIGS. 9 and 10 in which a cathode K constitutes the electron beam generating sources K_1, K_2 and K_3. A first control grid G_1 which, as shown on FIGS. 11 and 12, comprises three grid members G_{11}, G_{12} and G_{13} is supported in close, opposing relationship to the electron-emitting end surface of cathode K. The three grid members G_{11}, G_{12} and G_{13} have apertures g_{11}, g_{12} and g_{13}, respectively, arranged on a straight line. A commmon grid G_2 having three apertures g_{21}, g_{22} and g_{23} formed therein is mounted in opposing, adjacent relationship to the grid G_1 with the apertures g_{21}, g_{22} and g_{23} thereof in alignment with the apertures g_{11}, g_{12} and g_{13}, respectively. The grid G_2 may be cup-shaped to include a disk **1** (FIGS. 11 and 12) having the apertures g_{21}, g_{22} and g_{23} therein at spaced locations on a diametrical line II—II and a cylindrical side wall **2** extending from the periphery of disk **1** in the axial direction away from grid G_1. Arranged in order following the grid G_2 in the direction away from control grid G_1 are successive, open-ended, tubular grids or electrodes G_3, G_4 and G_5 (FIG. 9).

Electrode G_3 includes relatively small diameter end portions **3** and **4** and a larger diameter intermediate portion **5**, and is supported with its end portion **3** extending into cup-shaped grid G_2 and spaced radially from side wall **2** of the latter. Electrode G_4 includes end portions **6** and **7** of a diameter larger than that of end portions **3** and **4** of electrode G_3 and an intermediate portion **8** of still larger diameter, and electrode G_4 is mounted so that end portion **4** extends into, and is spaced radially inward from end portion **6**. Electrode G_5 includes end portions **9** and **10** of a diameter smaller than that of end portion **7** and an intermediate, relatively larger diameter portion **11**, and electrode G_5 is mounted so that its end portion **9** extends into, and is spaced radially inward from end portion **7** of electrode G_4. The several electrodes G_3, G_4 and G_5, grids G_1, G_2 and cathode K are all assembled together in the above described relation by means of suitable supports **12** of insulating material. Further, a getter chamber GT is provided around the end portion **10** of electrode G_5.

In operating the electron gun of FIG. 9, appropriate voltages are applied to grids G_1 and G_2 and to electrodes G_3, G_4 and G_5. For example, a voltage of 0 to −400 v. is applied to the grid G_1 (G_{11}, G_{12} and G_{13}), a voltage of 0 to 500 v. is applied to the grid G_2, a voltage of 13 to 20 kv. is applied to the electrodes G_3 and G_5, and a voltage of 0 to 400 v. is applied to the electrode G_4, with the voltage distributions with respect to the grids and electrodes G_1 to G_5, and their lengths and diameters are substantially identical with those of a unipotential-single beam type electron gun which includes a first single grid member and a second grid provided with a single aperture. With the applied voltage distribution described above, an electron lens field is established between grid G_2 and the end **3** of electrode G_3 which corresponds to the auxiliary lens L' of FIG. 5, and an electron lens field corresponding to the main lens L of FIG. 5 is formed at the axial center of electrode G_4 by the electrodes G_3, G_4 and G_5. In one operation of the electron gun, bias voltages of 100 v., 0 v., 300 v., 20 kv., 200 v., 20 kv., are applied to the electrodes K, G_1, G_2, G_3, G_4, and G_5 respectively.

In order to cause convergence of the beams B_1 and B_3 which emerge from electrode G_5 along divergent paths, the electron gun of FIG. 8 further has deflecting means F that includes shielding plates P and P' provided in spaced opposing relationship to each other and extending axially from the free end of electrode G_5. Deflecting means F further includes converging deflector plates Q and Q', which are outwardly convexly bent or curved, for example, and are mounted in spaced opposing relation to the outer surfaces of shielding plates P and P', respectively. The plates P and P' and the plates Q and Q' are disposed so that the beams B_1, B_2 and B_3 pass between the plates P and Q, between the plates P and P' and between the plates P' and Q', respectively. A voltage equal to that imparted to the electrode G_5 is applied to the plates P and P', and a voltage lower than that applied to the plates P and P' by 200 to 300 v. is applied to the plates Q and Q'. Thus, deflecting voltage differences are applied between the plates P and Q and between the plates P' and Q' which respectively constitute the deflectors F_1 and F_2 of FIG. 5 and are adapted to improve the deflecting action to the beam B_1 and B_3, respectively, as described above in connection with FIG. 5.

Thus, the three beams B_1, B_2 and B_3 emanating from the cathode K are made to pass through the apertures g_{11}, g_{12} and g_{13} of grid members G_{11}, G_{12} and G_{13} and are modulated with three different signals applied between the cathode K and the grid members G_{11}, G_{12} and G_{13}. The beams B_1, B_2 and B_3 pass through the comon auxiliary lens L' which is formed mainly by the Grid $_2$ and electrode G_3 and cross each other at the center of the main lens L which is constituted mainly by the electrodes G_3, G_4 and G_5. Then the beams B_1, B_2 and B_3 pass between the plates Q and P, between the plates P and P' and between the plates P' and Q' respectively, after having left the electrode G_5. Since plates P and P' are at the same potential, beam B_2 is not deflected, but the beams B_1 and B_3 which emerge from lens L along divergent paths are deflected, so that the three beams B_1, B_2 and B_3 are made to converge at a point on the electron-receiving station.

In the embodiment described above with reference to FIGS. 9 and 10, it is necessary that signals be separately applied to the three grid members G_{11}, G_{12} and G_{13} constituting the first grid G_1 since the three beam sources K_1, K_2 and K_3 are provided on the single cathode K. To meet such requirement, the three rectangular plate-like grid members G_{11}, G_{12} and G_{13} which are respectively formed with the apertures g_{11}, g_{12} and g_{13} have connector tabs **13** extending therefrom to receive the signals for modulating the electron beams independently of each other.

In order that the positional relationship of the apertures g_{11}, g_{12} and g_{13} of grid members G_{11}, G_{12} and G_{13} will be precisely predetermined, and that the apertures g_{11}, g_{12} and g_{13} will be concentrically aligned with apertures g_{21}, g_{22} and g_{23} of the second grid G_2 with a predetermined distance D being maintained between the second grid G_2 and the first grid members G_{11}, G_{12} and G_{13}, two ceramic insulator pieces **14**, each having a thickness D, are interposed between grids G_1 and G_2. Each of these insulator pieces **14** has a conductive layer **15** covering an entire surface thereof, as by metallizing that surface. Also, three conductive layers M_1, M_2 and M_3 extend across the width of the opposite surface of each insulator piece in uniformly longitudinally spaced relationship to each other. The insulator pieces **14** are disposed on the disk of the second grid G_2 in symmetrical, spaced relationship to the line II—II on which apertures g_{21}, g_{22} and g_{23} are arranged, and pieces **14** are integrally attached to the second grid G_2 at their conductor layers **15**, as by brazing. The grid members G_{11}, G_{12} and G_{13} bridge the space between insulator pieces **14** and are secured, as by brazing to the conductive layers M_1, M_2 and M_3 provided on the insulator pieces.

FIG. 13 shows, by way of example, a single electron gun A' according to the present invention applied to a chromatron type color picture tube. The electron gun A' comprises three electrically separated cathodes K_R, K_G and K_B to which "red," "green" and "blue" video signals are respectively supplied. The three cathodes are arranged with their electron emitting surfaces in a straight line so as to be aligned with similarly arranged apertures g_{1R}, g_{1G} and g_{1B} in a plate-like grid G_1. A second cup-shaped grid G_2 has an end plate disposed adjacent grid G_1 and formed with three apertures g_{2R}, g_{2G} and g_{2B} which are respectively aligned with apertures g_{1R}, g_{1G} and g_{1B}. As in the previously described embodiment, electron gun A' has electrodes G_3, G_4 and G_5 arranged successively to define the auxiliary lens L' and the main lens L.

Voltages based on the cathode voltages which are equal to those described above with reference to FIG. 9 are applied to the grids G_1 and G_2 and the electrodes G_3, G_4 and G_5 of the gun A'. Thus, beams B_R, B_G and B_B emanating from the cathodes K_R, K_G and K_B are made to pass through apertures g_{1R}, g_{1G} and g_{1B} of the first grid G_1 and apertures g_{2R}, g_{2G} and g_{2B} of the second grid G_2 and then through the auxiliary lens L' by which the beams are made to cross each other at the optical center of the main lens L. The beams B_R and B_B emerge from main lens L along divergent paths. As in the previously described embodiment, convergence deflector means F comprising deflectors F_1 and F_2 formed by shielding plates P and P' and deflecting plates Q and Q' are along the paths of the three beams B_R, B_G and B_B from the main lens L. The three beams B_R, B_G and B_B, after being acted upon by the convergence deflector means F, impinge on a color screen S, comprised of sets of "red," "green" and "blue" phosphor stripes S_R, S_G and S_B successively arranged on a face plate FP, after passing through a perforated electrode or shadow mask G_P provided in front of color screen S and having a medium high voltage V_M applied thereto. Voltages V_P and V_Q applied across the electrode plates P and Q and across the plates P' and Q' of convergence deflector means F are selected so that the three beams B_R, B_G and B_B are made to cross each other at the position of the mask G_P and thus made to land only on the corresponding phosphor stripes S_R, S_G and S_B. In this case, of course, the beams B_R, B_G and B_B, while converging at the mask G_P, are focused on the screen S.

The usual horizontal and vertical deflection means, as indicated by the yoke D, are provided for horizontally and vertically scanning the three beams simultaneously with respect to the screen S as in the conventional picture tube.

Thus, by supplying "red," "green" and "blue" color video signals between the cathodes K_R, K_G and K_B and the grid G_1, respectively, the three beams B_R, B_G and B_B are intensity-modulated, whereby a color picture is produced on the color screen.

Although the convergence deflection means F described above in connection with the electron gun of each of FIGS. 9 and 13 is of the electrostatic type, it is to be understood that each such deflection means F of the electrostatic type may be replaced by one of a magnetic type, for example, as illustrated on FIGS. 14A and B. Such deflection means F' of the magnetic type is shown to comprise a magnetic shield member **16** which may be in the form of a tube of rectangular cross-section arranged axially after the electrode G_5 (which is not shown on FIG. 14A) so as to permit the passage therethrough of the center beam B_2 (FIG. 9) or B_G (FIG. 13). Extending from one side **16**a of shield member **16** are two magnetic plates **17**a and **17**b which are in opposing, spaced relation to each other so as to permit the passage therebetween of the beam B_1 or B_R, and a similar pair of magnetic plates **18**a and **18**b extend from the other side **16**b of shield member **16** to permit the passage therebetween of the third beam B_3 or B_B. The edge portions of the plates **17**a and **17**b and of the plates **18**a and **18**b which are adjacent the shield member **16** are preferably bent so as to converge toward each other in the direction toward member **16**, as particularly shown on FIG. 14B. Further, the outer edge portions **19**a and **19**b of the plates **17**a and **17**b are preferably bent outwardly away from each other to extend along the inner wall surface of the neck portion of the tube envelope indicated at N on FIG. 14B. The outer edge portions of plates **18**a and **18**b are similarly bent away from each other, as at **20**a and **20**b. Such bent outer edge portions **19**a, **19**b, **20**a and **20**b form magnetic poles. Provided at the outside of the tube neck N are electromagnets **21** and **22** respectively including windings **23** and **24** on cores **25** and **26**. The core **25** has magnetic pole portions **25**a and **25**b disposed in opposing relation to poles **19**a and **19**b, respectively, and the core **26** similarly has pole portions **26**a and **26**b in opposing relation to poles **20**a and **20**b, respectively.

With the above described arrangement, the three beams B_1, B_2 and B_3 which have been made to cross each other at the optical center of the main lens L and then emerge from the electrode G_5 respectively pass between the opposing magnetic plates **17**a and **17**b, through the shield member **16** and between the opposing magnetic plates **18**a and **18**b. The beam B_2 is not deflected since it is shielded from the external magnetic field by the member **16**, while the side beams B_1 and B_3 are deflected by reason of the magnetic flux distributions between the magnetic plates **17**a and **17**b and between the plates **18**a and **18**b which result from static convergence current flow through the electromagnets **21** and **22**, whereby the three beams B_1, B_2 and B_3 are made to converge as desired, either at a point on the phosphor screen or on the shadow mask in front of the latter. Of course, it is possible to superimpose dynamic convergence currents on the static convergent currents flowing through the electromagnets **21** and **22** so that, in that case, separate dynamic convergence is not required.

Due to the fact that the inner edge portions of magnetic plates **17***a*, **17***b* and **18***a*, **18***b* adjacent the sides **16***a* and **16***b* of shield member **16** are convergent or inwardly bent, as shown in FIG. 14B, the beams are made to come very close to each other, that is, they are made to come very close to the magnetic shield member **16** so that it is possible to effectively prevent disturbance of the magnetic field at the positions of the beams B_1 and B_3 by the magnetic flux passing from the magnetic plates **17***a*, **17***b*, **18***a*, **18***b* to the magnetic shield member **16**. Thus, it is possible to effectively prevent distortion of the beam spots on the phosphor screen. If the distance between the opposing magnetic plates is *a*, the length of the bent portion of each magnetic plate is *c*, the distance between the free edges of the converging bent inner portions is *b*, and the relatively small dimension of the rectangular cross-section of the magnetic shield member is *d*, the best results have been attained when $b/a=0.625$, $d/2a=c/a=0.325$ and the angle between the inner edge bent portions is in the range of 30° to 60°. If the inner edge portions of the magnetic plates adjacent the sides of the magnetic shield member **16** are not bent, the magnetic field is non-uniformly distributed by reason of the fact that the magnetic flux at the positions of the beams B_1 and B_3 is curved under the influence of the magnetic flux passing from the magnetic plates **17***a*, **17***b* and **18***a*, **18***b* toward the magnetic shield member **16**. The distorting effect of such non-uniform magnetic field becomes great especially when the distance between the adjacent beams is reduced so that the beams are made to come close to the side surfaces of the magnetic shield member **16**. Such distorting effect can be effectively avoided by bending the magnetic plates as described above.

It will be readily apparent that, if desired, the convergence electromagnets **21** and **22** can be replaced by permanent magnets.

In the foregoing, electron guns embodying this invention have been described as being applied specifically to color picture tubes in which a single gun is employed to produce three electron beams which are intensity modulated with the usual "red," "green" and "blue" color signals. However, it is obvious that an electron gun in accordance with this invention can be used in any other cathode ray tube requiring a plurality of beams which are to be focused at a common spot or at separated spots on an electron-receiving screen.

Although illustrative embodiments of electron guns according to this invention have been described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be made therein by one skilled in the art without departing from the scope or spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a cathode ray tube having an electron-receiving screen, a single electron gun comprising beam producing means directing a plurality of electron beams toward said screen, means to cause said beams to intersect each other at a point in said tube intermediate said beam producing means and said screen, and focusing lens means common to all of said beams and being arranged in the paths of the beams to focus the latter on said screen, said lens means having an optical center and being located to dispose said optical center substantially at said point at which the beams intersect, thereby to avoid the effects of coma and spherical aberration.

2. Apparatus for the reproduction of images in color, comprising an electron receiving screen, an electron gun, said electron gun having means for generating a plurality of electron beams directed toward said screen, means for modulating said electron beams with color video signals, means to cause said electron beams to intersect at a location between said electron beam generating means and said receiving screen, focusing lens means positioned to focus said beams on said screen, and said focusing lens means having an optical center and being positioned to dispose the optical center thereof substantially at said location at which the electron beams intersect.

3. An electron gun for use in a cathode ray tube having a receiving screen, said gun comprising beam generating means for producing a plurality of electron beams, means to cause said beams to intersect, focusing lens means positioned to focus said beams on said screen, said focusing lens means having an optical center, and said focusing lens means being positioned to dispose the optical center thereof substantially at the location at which said beams intersect whereby the effects of certain optical aberrations are diminished.

4. An electron gun for use in a cathode ray tube, said gun comprising beam generating means for producing a plurality of electron beams, means to cause said beams to intersect substantially at a common location, focusing lens means operative to focus said beams in a plane spaced from said location at which said beams intersect, said focusing lens means having an optical center, and said focusing lens means being positioned to dispose the optical center thereof substantially at the location at which said beams intersect whereby the effects of certain optical aberrations are diminished.

5. A cathode ray tube comprising beam producing means for producing a plurality of electron beams, a receiving screen positioned to have said beams impinge thereon, means to cause said beams to intersect at a location in said tube between said beam producing means and said screen, focusing lens means positioned to focus said beams on said screen, said focusing lens means having an optical center, and said focusing lens means being positioned to dispose the optical center thereof substantially at the location at which said beams intersect whereby the effects of certain optical aberrations are diminished.

6. A cathode ray tube according to claim **5**, in which said lens means includes a plurality of electrodes at different electrical potentials to establish an electron lens field for said focusing of the beams passing therethrough.

7. A cathode ray tube according to claim **5**, in which said beam producing means includes individual beam sources, and said means to cause said beams to intersect each other at said location supports said individual beam sources with the beams issuing therefrom converging to said location.

8. A cathode ray tube according to claim **5**, in which said beams issue substantially parallel to each other from said beam producing means, and said means to cause the beams to intersect at said location of the optical center includes auxiliary lens means disposed between said beam producing means and said focusing lens means and causing convergence of the beams to said location.

9. A cathode ray tube according to claim **8**, in which said auxiliary lens means includes electrodes at different electrical potentials to establish an electron lens field through which the beams pass for said convergence at said location.

10. A cathode ray tube according to claim **5**, in which deflection means are located between said focusing lens means and said screen to deflect those beams which emerge from said focusing lens means along divergent paths whereby to cause convergence of said beams at a common area on said screen.

11. A cathode ray tube according to claim **10**, in which said screen includes a phosphor screen member and a perforated shadow mask in front of said phosphor screen member, and in which said lens means focuses all of said beams at said phosphor screen member and said deflection means converges all of said beams to a common location at said shadow mask.

12. A cathode ray tube according to claim 10, in which said deflection means includes spaced plates at different electrical potentials disposed at opposite sides of each of said divergent paths to electrostatically deflect the beam in the respective path.

13. A cathode ray tube according to claim 10, in which said deflection means includes means establishing a magnetic field across each of said divergent paths to magnetically deflect the beam in the respective path.

14. A cathode ray tube according to claim 10, in which said beam producing means defines sources for three of said beams, with one of said sources being at the optical axis of said focusing lens means and the other two sources being equally spaced from said one source at opposite sides of the latter on a straight line extending diametrically across said optical axis so that only the beams from said other two sources follow divergent paths upon emerging from said focusing lens means.

15. A cathode ray tube according to claim 14, in which said deflection means includes a pair of first plates at equal electrical potential disposed at opposite sides of said optical axis for the passage therebetween of the beam from said one source upon emergence thereof from said focusing lens means, and second plates spaced outwardly from said first plates for the passage between said first and second plates of said beams from said other two sources, said second plates being at an electrical potential different from that of the first plates to electrostatically deflect the respective beams from said other two sources in the direction toward said optical axis.

16. A cathode ray tube according to claim 14, in which said deflection means includes a tubular magnetic shield arranged along said optical axis for the passage therethrough of the beam from said one source upon emergence from said lens means, pairs of spaced magnetic plates extending outwardly from opposed sides of said shield for the passage between said pairs of plates of the beams from said other two sources, and magnet means operatively associated with said pairs of plates to establish, between the plates of each pair, a magnetic field for deflecting the beam passing therethrough toward said optical axis.

17. A cathode ray tube according to claim 16, in which the plates of each of said pairs have inner edge portions which converge toward each other in the direction toward the adjacent side of said shield for minimizing distortion of the respective beams by non-uniformity of the magnetic field between said plates.

18. A cathode ray tube according to claim 5, in which said beam producing means includes cathode means emitting electrons, and first and second grid means arranged successively in adjacent, opposing relation to said cathode means and to each other, respectively, and having aligned apertures for each of said beams to form the latter parallel to each other.

19. A cathode ray tube according to claim 18, in which said second grid means is in the form of a single plate having all of the respective apertures therein, said focusing lens means includes a plurality of tubular electrodes arranged successively in order after said second grid means and being at different electrical potentials to establish an electron lens field for the focusing of all of the beams passing therethrough, and said means to cause the beams to intersect at said location includes an annular side wall extending from the periphery of said plate of the second grid means and being at an electrical potential different from that of the next adjacent electrode of said focusing lens means to establish an auxiliary electron lens field for converging the beams formed in parallel relation to each other.

20. A cathode ray tube according to claim 18, in which said cathode means includes a single cathode member having an electron emitting surface, said first grid means includes a plurality of grid members each corresponding to one of said beams and having a respective aperture therein, said grid members of the first grid means being disposed in confronting, adjacent relation to said electron emitting surface, said second grid means includes a single plate in confronting, adjacent relation to said members of the first grid means, and insulating and spacing members are interposed between, and bonded to said grid members of the first grid means and said plate for maintaining predetermined relative spacing and alignment of said apertures in the first and second grid means.

21. An electron gun for use in a cathode ray tube, said gun comprising beam generating means for producing a plurality of electron beams, means to cause said beams to intersect, focusing lens means positioned to focus said beams, said focusing lens means having an optical center, and said focusing lens means being positioned to dispose the optical center thereof substantially at the location at which said beams intersect whereby the effects of certain optical aberrations are diminished.

22. An electron gun in accordance with claim 21 in which said beam generating means includes one cathode for emitting electrons and at least two grid members positioned in opposing relationship to the electron emitting surface of said cathode.

23. An electron gun in accordance with claim 21 in which said individual beams generated by said beam generating means have a cross-sectional area less than the cross-sectional area at the optical center of said focusing lens where said beams intersect.

24. An electron gun according to claim 21, having deflection means for deflecting those beams which emerge from said focusing lens means along paths diverging from the optical axis of said focusing lens means to cause convergence for all of said beams in a common location.

25. An electron gun in accordance with claim 24 in which said beam producing means includes cathode means emitting electrons, and first and second tubular grid means arranged successively in adjacent, opposing relation to said cathode means and to each other respectively and having aligned apertures for each of said beams to form the latter parallel to each other.

26. An electron gun in accordance with claim 21 in which said lens means includes a plurality of electrodes at different electrical potentials to establish an electron lens field therebetween for said focusing of the beams passing therethrough.

27. An electron gun in accordance with claim 26 in which said lens means further includes at least two tubular electrodes arranged in successive order with said electron lens field being established therebetween.

28. An electron gun in accordance with claim 27 in which said beams issue substantially parallel to each other from said beam producing means, and said means to cause the beams to intersect includes auxiliary lens means disposed between said beam producing means and said focusing lens means.

29. An electron gun in accordance with claim 28 in which said auxiliary lens means includes at least two tubular electrodes at different electrical potentials to establish an electron lens field through which the beams pass for convergence.

30. An electron gun in accordance with claim 21 in which said means to cause the beams to intersect includes beam generating means arranged on an arcuate surface whereby said beams issue from said beam generating means in a manner to intersect substantively at the optical center of said focusing lens.

31. An electron gun in accordance with claim 30 in which the center of said arcuate surface is on the same axis as the optical center of said focusing lens.

32. An electron gun in accordance with claim 21 in which said beam generating means includes at least two cathodes for emitting electrons and one grid member positioned in opposing relationship to the electron emitting surfaces of said cathodes.

33. An electron gun in accordance with claim **32** in which said cathodes are arranged in a straight line and aligned with apertures provided in said grid member.

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RODNEY D. BENNETT, *Primary Examiner.*

M. F. HUBLER, *Assistant Examiner.*

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313—70

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,448,316 Date: June 3, 1969

SUSUMU YOSHIDA ET AL

It is certified that error appears in the above-identi patent and that said Letters Patent be hereby corrected as shown be

In the Specification: Col. 1, line 8, "Mar. 25" should read --Mar. 22--. Col. 3, line 12, after "ing" insert --to--. Col. 5, line 18, "divering" should read --diverging--; and line 67, "commmon" should read --common--. Col. 6, line 31, after "voltage" insert --of cathode K as the reference. Therefore, the voltage--; line 47, "Fig. 8" should read --Fig. 9--; line 65, "improve" should read --impart--; line 73, "comon" should read --common--; and line "Grid $_2$" should read --grid G_2--. Col. 7, line 10, "station" shoul read --screen--.

SIGNED AND SEALED

APR 14 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.

Commissioner of Patents