Fig. 1
ABSTRACT OF THE DISCLOSURE

A cathode-ray tube especially with a wide deflection angle having a focussing lens for focussing an electron beam produced by an electron gun at an elongate spot on a screen which extends transversely to the longitudinal axis of tube. Deflection means are provided for deflecting the electron beam in the transverse as well as longitudinal directions of the spot. An astigmatic lens is provided for obtaining an electron beam structure in which the electron beam is focussed with respect to rays lying in a plane parallel to the transverse direction substantially on the screen and with respect to rays lying in a plane parallel to the longitudinal direction of the spot at a point in front of the screen on the side facing the electron gun.

The invention relates to an arrangement including a cathode-ray tube in which an electron beam produced by an electron gun and focussed by means of a focussing lens strikes a target at a narrow elongate spot, the arrangement including means for deflecting the electron beam in the transverse direction of the spot of the non-deflected electron beam and means for deflecting the electron beam in the longitudinal direction of the spot of the non-deflected electron beam. The direction corresponding to the transverse direction of the spot of the non-deflected electron beam will be referred to hereinafter as the X-direction. The direction corresponding to the longitudinal direction of the spot of the non-deflected electron beam will be referred to as the Y-direction.

The invention further relates to a cathode-ray tube for use in such an arrangement.

Although in many known arrangements, a cathode-ray tube can be employed the electron beam of which strikes a target at a circular spot, it is known that it is required for a satisfactory operation of certain arrangements having a cathode-ray tube that the electron beam should strike a target at a narrow elongate, for example, elliptical, spot. This requirement is generally due to the specific structure of the target. It is imposed, for example, on arrangements of the said kind in which the target comprises a mosaic of separate ellagongate conducting elements, and on color television display arrangements of the kind in which the target of the cathode-ray tube comprises narrow phosphor strips. A specific type of the latter arrangements is a display arrangement of the so-called "index" type, in which the cathode-ray tube is a so-called "index-tube." The target of an "index tube" comprises a large number of narrow substantially parallel phosphor strips, adjacent strips emitting light of different colors when struck by electrons, while sequential phosphor strips are separated by black inoperative strips. The phosphor strips and the black strips are covered on the side of the electron gun with a layer which is permeable to electrons and on which are arranged evenly spaced so-called "index strips" which are parallel to the phosphor strips. The index strips allow the position of the electron beam to be determined. The width of the phosphor strips and the black strips must be extremely small in order that a high-quality image may be obtained. It is often desirable for this width to be at the most a few tenths of a millimeter. As a result, the electron beam must fulfill stringent requirements. A high-fidelity color reproduction is obtained only if the electron beam does not strike more than one phosphor strip at a time. Therefore, the dimension of the spot of the electron beam at a right angle to the phosphor strips must be approximately equal to the width of said phosphor strips. A sufficient brightness can be obtained only with beam currents of up to a few milliamperes. In order to obtain with these high currents a sufficiently small beam dimension in the direction at right angles to the phosphor strips means to deflected the electron beam and to avoid phosphor saturation at a high beam power as far as possible, it is required that the dimension of the spot of the electron beam in the direction of the phosphor strips be larger than the dimension of the spot in the direction at right angles to the phosphor strips, which latter dimension must be small with regard to the width of said strips.

A known arrangement of the kind mentioned in the first paragraph has a focussing lens constituted by a ring of ferromagnetic material. The ring is arranged so as to concentrically surround the path of the electron beam and is magnetized in a direction parallel to said path. The outer surface of the ring supports at least one block of ferromagnetic material provided in the non-magnetized state. In this arrangement, an elongate spot is obtained in that due to the presence of the block of ferromagnetic material the cross-section of the electron beam, which would be rotation-symmetrical in the absence of such a block, is lengthened in the Y-direction. For this purpose, the block is arranged so that a line joining this block and the path of the electron beam is substantially parallel to the desired Y-direction. The dimensions suitable for the block are determined in practice by starting from a rotation-symmetrical electron beam being focussed to the optimum on the target and by providing various blocks of ferromagnetic material until the desired beam cross-section is attained.

The above known arrangement has the disadvantage that the shape and the position of the spot of the deflected electron beam differ from the shape and the position of the spot of the non-deflected electron beam. The disadvantage becomes particularly manifest in an embodiment of this arrangement for deflection through large angles. Especially in a display arrangement of the "index type," the length of the spot generally varies too rapidly as a function of the deflection angle, more particularly if the deflection means serve to keep the spot narrow. At a given deflection angle, the length of the spot generally has a minimum value, at which during operation of the display arrangement a dark ring or a ring of a given color is visible on the target due to phosphor saturation. The color of the ring depends upon the phosphors used. By the twist of the spot resulting in an effective increase in width of the spot, the spot can extend at the corners of the target over more than one phosphor strip, which involves a strong deterioration of the quality of the color reproduction. An erroneous index information may even be obtained in that the beam strikes several index strips at a time.

The invention has for an object to provide an arrangement in which these disadvantages are obviated.
An arrangement according to the invention including a cathode-ray tube in which an electron gun produced by an electron gun and focussed by means of a focussing lens strikes a target at a narrow elongate spot, the arrangement including means for deflecting the electron beam in the transverse direction of the spot of the non-deflected electron beam (Y-direction) and means for deflecting the electron beam in the longitudinal direction of the spot of the non-deflected electron beam (Y-direction), includes an astigmatic lens to obtain an electron-beam structure in which the non-deflected electron beam is focussed with respect to rays lying in a plane parallel to the target and with respect to rays lying in a plane parallel to the said longitudinal direction (Y-direction) at a point located in front of the target on the side of the electron gun. It should be noted that the term "point" in this case indicates a region in which the rays meet and is not to be interpreted mathematically.

The invention is based on the discovery that an electron beam of this structure can strike the target at a spot which remains narrow upon deflection of the electron beam but whose length is comparatively constant, while moreover the effective increase in width of the spot at the commencement of its trajectory to its target can be kept small. The electron beam is focussed with respect to rays lying in a plane parallel to the X-direction substantially on the target so that the spot of the non-deflected electron beam has a small width. In order that the width of the spot may be kept small upon deflection of the electron beam, deflection beams are preferably employed of a kind such that the meridional image plane of the means for deflection in the X-direction and the sagittal image plane of the means for deflection in the Y-direction and the sagittal image plane of the means for deflection in the Y-direction coincide as far as possible with the target plane. (Sagittal focal lines are focal lines in the plane passing through the axis of the opening of the beam, Meridonal focal lines are focal lines at right angles to the plane passing through the axis of deflection means and the axis of the beam. The sagittal image plane is the plane in which the sagittal focal lines are imaged. The meridional image plane is the plane in which the meridional focal lines are imaged. For a more complete explanation of the terms "sagittal" and "meridional" reference may be had to U.S. Patent 2,866,129 and U.S. Patent 2,866,125 wherein these terms are explained in extenso and FIG. 4 wherein the beam is deflected in Y-direction by the Y-deflection means 21. The beam is focussed in lines perpendicular to the Y-direction, or course, (and so deflected), lying in the plane of the figure at 14, 17 and 18 (the line at 17 being reduced to a point). These lines are sagittal focal lines (in the plane through Y and the axis of the beam). The surface comprising these lines is the sagittal image plane of the Y-deflection means 21. The direction at the same time is concentrated in lines perpendicular to the plane of the figure (at right angles to the plane through Y and the axis of the beam). These lines are the meridional focal lines in the meridional image plane 26 of the Y-deflection means.) Since the electron beam is focussed with respect to rays lying in a plane parallel to the Y-direction at a point located in front of the target (viewed from the electron gun), the sagittal image plane of the means for deflection in the X-direction and the meridional image plane of the means for deflection in the Y-direction are located in front of the target and the curvature of these image planes has a smaller influence on the image of the target than has heretofore, in which the electron beam is focussed with respect to rays lying in a plane parallel to the Y-direction at a point located behind the target. In contradistinction to the conventional beam structure, in which the sagittal image plane of the means for deflection in the X-direction is projected on the deflection means for deflection in the Y-direction may even intersect the target so that the length of the spot exhibits a sharp minimum, a beam structure according to the invention avoids such a minimum. It has been found that the effective increase in width of the spot due to its twist can be kept smaller in a beam structure according to the invention than in the said conventional structure. The relative lengthening of the spot upon deflection and the twisting of the spot upon deflection both depend upon the distance between the point at which the electron beam is focussed with respect to rays lying in a plane parallel to the Y-direction and the target and upon the coefficients of aberration of the deflection means. With given deflection means it has been found that this relative lengthening and this twisting generally (the minimum) accordingly by a given choice of the said distance; however, in embodiments of the arrangement according to the invention, this distance can be chosen so that a reasonable compromise is attained between the variation in length and the twisting.

The arrangement according to the invention can be constructed so that the focussing lens comprises a lens element of the said astigmatic lens. The focussing lens may comprise, for example, a quadrupolar lens in order to obtain the desired beam structure.

The arrangement according to the invention can also be constructed so that the first grid has a non-rotation-symmetrical "trioide gun" comprising a cathode, a first grid and a last grid acting as an acceleration electrode, the first grid having a non-rotation-symmetrical opening, the minor axis of which is parallel to one of the directions of deflection and the major axis of which is parallel to the other direction of deflection, while this opening is substantially symmetrical relative to said axes. The opening in the first grid may have different geometric forms having two orthogonal axes of symmetry. An elliptical opening has the advantage that it can be provided in the grid in a simple manner, for example, by punching. The provision of angular openings generally requires more complicated techniques such as spark erosion. This grid may be in the form of a non-rotation-symmetrical "trioide gun" comprising a cathode, a first grid and a last grid acting as an acceleration electrode. In such a grid, separate longitudinal beam cross-overs spaced by different distances from the cathode are obtained in the direction of the minor axis and in the direction of the major axis of the opening in the first grid so that the increase in cross-section of the electron beam due to space charge is smaller in such an electron gun than in a rotation-symmetrical electron gun in which one pointed beam cross-over is obtained. The minor axis of the opening in the first grid is preferably parallel to the X-direction in order to obtain that the spherical aberration in the gun is small with respect to rays lying in a plane parallel to the X-direction. Such an arrangement comprises besides a trioide gun orientated in this manner an astigmatic lens element in order to ensure that the order of succession of the images of the beam cross-overs will be just opposite to that of the corresponding beam cross-overs in the electron gun in which the beam cross-over for rays in a plane parallel to the minor axis of the opening in the first grid lies closer to the cathode than the beam cross-over for rays in a plane parallel to the major axis of the said opening.

It should be noted that a non-rotation-symmetrical trioide gun is known per se, but its possibilities of improvement in an arrangement in which an extremely narrow elongate spot remaining constant upon deflection is desired, have not been described.

The electron gun preferably comprises a second grid which is interposed between the first and the last grid and which together with the cathode, the first grid and the last grid forms the said astigmatic lens. This has the advantage that, even if the minor axis of the opening in the first grid is parallel to the X-direction,
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the use of a simple rotation-symmetrical focussing lens will be sufficient. The focussing lens is preferably an electrostatic rotation-symmetrical focussing lens. The electron beam is focussed in the first grid, or it may be pieced together to form an assembly which can be readily mounted in the cathode-ray tube. The spherical aberration in the direction of the minor axis of the opening in the first grid can be considerably smaller than in a triode gun due to the presence of the second grid. The geometry of the openings in the first grid may be chosen so that the occurrence of a beam cross-over in the electron gun with respect to rays in a plane parallel to the direction of the major axis of the opening in the first grid is avoided, as a result of which the detrimental effect of the increase in cross-section of the electron beam in the electron gun due to space charge can be smaller than in a triode gun. The opening in the second grid is preferably rotation-symmetrical so that the second grid can be readily manufactured and centered.

The invention further relates to a cathode-ray tube for use in the arrangement described, more particularly to a cathode-ray tube in which the target has narrow substantially parallel phosphor strips emissive of light of different colors. These phosphor strips may be extremely narrow, especially in a favorable embodiment in which the cathode-ray tube comprises an electron gun and a rotation-symmetrical electrostatic focussing lens, the electron gun comprising a cathode, a first grid, a second grid, and a last grid, which first grid has a non-rotation-symmetrical opening, and a major axis of which is substantially parallel to the phosphor strips and the minor axis of which is substantially orthogonal to said strips.

The invention will be described with reference to the accompanying drawings, in which FIG. 1 illustrates the principles of a known display arrangement of the index type;

FIG. 2 shows diagrammatically the target of the known display arrangement of FIG. 1;

FIG. 3 shows the spot of the electron beam on various parts of the target of the known display arrangement of FIG. 1;

FIG. 4 illustrates the behaviour of the electron beam in the known arrangement of FIG. 1;

FIG. 5 illustrates the behaviour of the electron beam in an arrangement according to the invention;

FIG. 6 shows an arrangement having a cathode-ray tube according to the invention;

FIG. 7 shows in greater detail elements of the cathode-ray tube of FIG. 6; and

FIG. 8 is a partial sectional view taken on the line VIII-VIII of FIG. 7.

FIG. 1 illustrates the known principle of a display arrangement of the index type, which is a typical example of an arrangement in which an electron beam should strike a target at an elongate spot. The figure shows diagrammatically an electron gun 1 of an index type by means of which an electron beam 2 is produced. The electron beam strikes a target 3, which is shown in part. The target is located on the front plate 4 of the index tube, which is shown in part. Between the electron gun 1 and the target 3 are interposed a focussing lens (not shown in FIG. 1) and deflection means (not shown in FIG. 1 either) for deflecting the electron beam over the target 3. The target 3 has a row of phosphor strips 5, 6 and 7, the strips 5 emitting blue light, the strips 6 emitting red light, and the strips 7 emitting green light when struck by the electron beam. Sequential phosphor strips are separated by black inoperative strips 8. The phosphor strips and the black strips are covered by a conducting layer 9 which is permalloy. In the figure the layer 9 is interrupted to show the phosphor strips. This layer 9 serves to reflect light to the front plate 4 and to protect the phosphor strips from ion bombardment. In the figure, before every other black strip, an index strip 10 is visible on the permeable layer 9. These strips 10 provide signals indicating the position of the electron beam. The strips 10 may comprise, for example, ultraviolet phosphor emitting light in the blue part of the spectrum. A pulse is emitted from an index strip when the beam is not deflected and in two positions (23) and (24) occupied by the beam after deflection. The non-deflected electron beam (22) is directed to the center 14 of A in FIG. 3. In the position 23, the electron beam is directed to the center 17 of D in FIG. 3. In the position 24, the electron beam is directed to the center 18 of G in FIG. 3. The non-deflected electron beam is focussed at a point 25 located behind the target and the meridional image plane 26 intersects the target at 17 so that upon deflection, the length of the spot first decreases to a sharp minimum at 17 and then rapidly increases.

FIG. 5 illustrates, like FIG. 1, the behavior of the electron beam, but now in an arrangement according to the invention. This figure shows diagrammatically the electron beam 102 in the plane passing through the axis 119 of the electron gun at right angles to the X-direction. The electrons are passing a focussing lens 120 (shown symbolically) and pass the deflection means 121 which are identical to the means 21 of FIG. 4. The non-deflected electron beam 122 strikes the target 103 at a spot which has the same shape and size as the spot of the non-deflected electron beam 22 of FIG. 4. The deflected beam is shown in FIG. 5 again in two positions (123) and (124). The non-deflected electron beam is focussed in the Y-direc-
tion at a point 125 located in front of the target so that the meridional image plane is formed at the area indicated by 126 and the length does not vary rapidly with the deflection angle and does not exhibit a sharp minimum upon deflection from the position of the non-deflected beam. In the embodiment of the invention shown in FIG. 6, reference numeral 40 indicates the vertical sectional view of a glass envelope of an index tube. The target 41 has the structure of the target (3) of FIG. 1. The target has 1200 vertical phosphor stripes 42 separated by black stripes. The width of the phosphor stripes and the black stripes is 0.21 mm. The index stripes 44 are disposed on the aluminum layer 43. The envelope accommodates the electron gun 45 and the rotation-symmetrical focusing lens 46. The electron gun 45 comprises a cathode 48, a first grid 49, a second grid 50 and a last grid 51 constituted by the spout of the electrode 52. The distance of the first grid 49 from the target plate is 385 mm. The rotation-symmetrical focusing lens 46 for electrostatic focusing of the electron beam produced by the electron gun comprises an electrode 52, a focussing electrode 53 and an end-electrode 54. The electrodes are centered with respect to the axis 55 of the tube. The supply leads and supporting means of the electrodes are not shown. The neck of the tube is surrounded at the area at which it terminates in the cone by deflection coils 47 for horizontal and vertical magnetic deflection. The electron beam can be deflected from the position in which it is not deflected by applying a magnetic field along a diagonal of the target through an angle of at most 55°. In technology, the index tube described may be referred to as "110° index tube," because the beam can be deflected from -55° to +55°.

The electron gun 45 and the focusing lens 46 of FIG. 6 are shown in a vertical sectional view in FIG. 7. This figure shows the electron-emissive cathode surface 56. Between the cathode surface 56 and the second grid 50v is interposed the wall 57 of the first grid 49 which has a thickness of 0.075 mm. The distance of the cathode surface 56 from the wall 57 of the first grid is 0.125 mm. The distance of the wall 57 of the first grid 49 from the second grid 50 is 0.250 mm. The distance of the wall 57 of the first grid from the last grid 51 is 7 mm. The electrode 52 has an inner diameter at the spout 51 of 4.5 mm, which increases to 20 mm. The focussing electrode 53 and the second grid 50 also have an inner diameter of 20 mm. The distance between the electrodes 52 and 53 and the distance between the electrodes 53 and 54 are both 2.5 mm. The distance of the wall 57 of the first grid 49 from the center of the focussing electrode 53 having a length of 35 mm is 60 mm. The wall 57 of the first grid 49 has an elliptical opening 58, the major axis of which is vertical and has a length of 1.035 mm. The horizontal minor axis of the opening 58 has a length of 0.350 mm. The second grid 50 has a rotation-symmetrical opening 59 which has an axial length of 0.600 mm and a diameter of likewise 0.600 mm. The shape of the openings 58 and 59 is illustrated in the sectional view of FIG. 8.

During operation of the arrangement (cf. FIG. 6), the electrodes have the following voltages relative to the cathode 48. The first grid 49 has a voltage lying between -270 v. and -170 v.; the second grid 50 has a voltage of 1500 v.; the end-electrode 54 has a voltage of 52,000 v.; the focussing electrode 53 has a voltage of 7200 v.; the end-electrode 54 has a voltage of 25,000 v.

At the voltage of -170 v. at the first grid, the beam current is 2 ma. The non-deflected electron beam is then focussed with respect to rays lying in planes parallel to the horizontal deflection substantially on the target 41 and with respect to rays lying in planes parallel to the vertical deflection at a "point" located approximately 140 mm. in front of the target on the side of the electron gun 45. The meridional image plane of the horizontal deflection coil and the sagittal image plane of the vertical deflection coil substantially coincide with the target.

Upon deflection of the electron beam, the length of the elliptical spot of the electron beam on the target plate increases uniformly to the length of the spot at the deflection angle of 55°, which length is smaller than twice the length of the spot of the non-deflected electron beam.

The twisting of the image remains below 20°.

What is claimed is:

1. A cathode-ray tube comprising a substantially planar electron receiving screen extending at right angles to the longitudinal axis of the tube, an electron gun including a cathode, a first grid and a last grid acting as an accelerating electrode for producing an electron beam, and a focussing lens for focussing the electron beam at a narrow elongate spot on said screen, first deflection means for deflecting the electron beam in the transverse direction of the spot, second deflection means for deflecting the electron beam in the longitudinal direction of the spot, and an astigmatic lens between the cathode and the screen for obtaining an electron beam structure in which the electron beam is focussed with respect to rays lying in a plane parallel to the said transverse deflection substantially on the screen and with respect to rays lying in a plane parallel to the said longitudinal deflection at a point located in front of the screen on the side facing the electron gun.

2. The combination as claimed in claim 1, wherein the meridional image plane of said first deflection means and the sagittal image plane of said second deflection means substantially coincide with the screen.

3. The combination as claimed in claim 1 wherein the said focussing lens comprises a lens element of the said astigmatic lens.

4. The combination as claimed in claim 3, wherein the said focussing lens comprises a quadrupolar lens.

5. The combination as claimed in claim 1 wherein the said electron gun comprises a lens element of the said astigmatic lens.

6. The combination as claimed in claim 5 wherein said first grid has a non-rotation-symmetrical opening the minor axis of which is parallel to one direction of deflection and the major axis of which is parallel to the other direction of deflection, said opening being substantially symmetrical with respect to the said axes.

7. The combination as claimed in claim 6 wherein the opening in the first grid is elliptical.

8. The combination as claimed in claim 6 wherein between the first and the last grid a second grid is interposed which together with the cathode, the first grid and the last grid constitutes the said astigmatic lens.

9. The combination as claimed in claim 8 wherein the opening in the second grid is rotation-symmetrical.

10. The combination as claimed in claim 6 wherein the focussing lens is a rotation-symmetrical focussing lens.

11. The combination as claimed in claim 10 wherein the focussing lens is an electrostatic rotation-symmetrical focussing lens.

12. A cathode ray tube comprising an electron gun including a cathode, a first grid and a last grid an accelerating electrode, a screen extending substantially at right angles to the longitudinal axis of the tube which luminesces under impact of electrons spaced from and in the path of an electron beam produced by said electron gun, a focussing lens for focussing the electron beam at a narrow elongate spot on the screen, and an astigmatic lens between the cathode and the screen for obtaining an electron beam substantially in which the electron beam is focussed with respect to rays lying in a plane parallel to the transverse direction substantially on the screen and with respect to rays lying in a plane parallel to the longitudinal direction of the spot at a point located in front of the screen on the side facing the electron gun.

13. A cathode-ray tube as claimed in claim 12, where-
in the screen comprises narrow substantially parallel phosphor strips emissive of light of different colors.

14. A cathode-ray tube as claimed in claim 13, wherein between the first grid and the last grid, a second grid is interposed, said first grid having a non-rotation symmetrical opening the major axis of which is substantially parallel to the phosphor strips and the minor axis of which is substantially orthogonal to said strips.

15. A cathode-ray tube as claimed in claim 14, wherein the focussing lens is electrostatic and rotation-symmetrical.
UNIVERS STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3524094 Dated August 11, 1970

Inventor(s) JAN HASKER and JOHANNES KAASHOEK

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 12, change "Dec. 2, 1967" to --December 22, 1967--;

Signed and sealed this 1st day of December 1970.

(SEAL)
Attest:
Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents