

"CATHODE-RAY TUBE"

The invention relates to a cathode-ray tube.

A cathode-ray tube is disclosed in Netherlands Patent Application 7902868, laid open to public inspection, and
5 comprises in an evacuated envelope means to generate at least one electron beam and to form a cross-over behind which, viewed in the direction of propagation of the electron beam, are provided successively an accelerating pre-focusing lens comprising a first and second lens electrode centred around
10 an axis, and a main focusing lens comprising at least two electrodes, the lens electrodes in use being coupled to a voltage applying means.

A cathode-ray tube can be used for displaying monochromatic or multicolour pictures, for example television pictures, in
15 which case the cathode-ray tube is a display tube comprising a display screen. Such a cathode-ray tube, however, may also be used to record pictures, in which case the cathode-ray tube is a camera tube having a photosensitive, for example photoconductive, layer.

20 The means to generate an electron beam and to form a cross-over are usually formed by a triode consisting of a cathode, a control grid and an anode. However, it is also possible to generate an electron beam by means of a semiconductor device as described in Netherlands Patent Application 7905470 laid open
25 to public inspection and to focus it to form a cross-over.

More particularly the cathode-ray tube described in the published Netherlands Patent Application 7902868 comprises a cathode, a control grid, a first lens electrode (termed G-2 in said Application) and a second lens electrode (termed G-3 in
30 said Patent Application). The cathode, control grid and first lens electrode ensure the generation of an electron beam which is focused into a cross-over in the proximity of the first lens electrode. The cross-over is displayed on the display screen of the cathode-ray tube by means of one or more focusing lenses.
35 The spot displayed on the display screen must have a good quality.

This means that the spot must have small dimensions and be surrounded by as little haze as possible. According to the published Netherlands Patent Application 7902868 a spot having a better quality is obtained by using a comparatively thick first lens electrode and by ensuring that a strong flat electric field is present between the first and the second lens electrodes and/or the main focusing lens has a larger object distance than has been usual so far. According to the said Patent Application the pre-focusing of the electron beam by the first accelerating focusing lens is preferably eliminated or is at least strongly reduced after the cross-over. Nevertheless, the improvements described do not lead to an optimum result.

It is therefore an object of the invention to improve the spot quality in a cathode-ray tube.

According to the present invention there is provided a cathode-ray tube comprising in an evacuated envelope means to generate at least one electron beam and to form a cross-over behind which, viewed in the direction of propagation of the electron beam, are provided successively an accelerating pre-focusing lens comprising a first and second lens electrode centred around an axis, and a main focusing lens comprising at least two lens electrodes, wherein the diameter of the aperture in the second lens electrode is smaller than twice the diameter of the aperture in the first lens electrode and the effective spacing S_{eff} between the first and the second lens electrodes is smaller than 1 mm, S_{eff} being defined as the minimum of the function

$$- \frac{\Delta V}{E(z)}, \text{ wherein}$$

ΔV is the voltage difference applied in use between the second and first lens electrodes and $E(z)$ is the electrical field strength existing in use between the first and second lens electrodes on the axis as a function of a place z on the axis.

The invention is based on the recognition of the fact that an electric field variation must be created between the first

and second lens electrodes such that the edge rays of the generated electron beam immediately after the cross-over are bent so much more inwardly than the remaining rays, that the edge rays of the electron beam in the main focusing lens are no longer edge rays. The result of this is again that the spherical aberration of the main focusing lens acts upon other rays than the spherical aberration of the beams in the pre-focusing lens. As a result of this, the total spherical aberration of the whole electron gun system is divided over more rays of the electron beam, as a result of which a decrease of the effect of the spherical aberration in the spot is obtained. Consequently, with beam currents remaining the same, the spot becomes smaller and is surrounded by less haze than in the electron guns used so far. The variation of the electrical field between the first and the second lens electrodes is determined by the spacing between said electrodes, the dimensions of the apertures in said electrodes and the potentials of said electrodes. The edge rays in the pre-focusing lens are sufficiently bent inwardly when the diameter of the aperture in the second lens electrode is smaller than twice the diameter of the aperture in the first lens electrode and the effective spacing S_{eff} between the first and second lens electrodes is smaller than 1 mm, as was already indicated. The electrical field on the axis between the two lens electrodes is fixed by the first derivative to the place z of the potential variation along the axis, hence

$$E(z) = - \frac{d V(z)}{d z}$$

The potential variation along the axis with given gun dimensions and given potentials on the electrodes can be measured and/or computed. The spacing between the first and the second lens electrodes is preferably smaller than 0.8 mm. The lower limit of said spacing is determined by the potentials at the electrodes and the electrode form, for example, the presence or absence of sharp edges. The spacing may not be chosen to be too small, for example smaller than 0.2 mm, because in that case

electrical breakdowns may occur.

Cathode-ray tubes in accordance with the invention having a very good spot quality are obtained if the diameter of the aperture in the first lens electrode is smaller than 0.9 mm and the diameter of the aperture in the second lens electrode is smaller than 1.6 mm, or if the diameter of the aperture in the second lens electrode is equal to or substantially equal to the diameter of the aperture in the first lens electrode. If the spacing between the first and the second lens electrodes is equal to or approximately equal to 0.4 mm, the possibility of the occurrence of electrical breakdowns is negligibly small.

The present invention will now be explained and described in greater detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a horizontal longitudinal sectional view through a cathode-ray tube made in accordance with the invention,

Figure 2 is a longitudinal sectional view through one of the electron guns as used in the cathode-ray tube shown in Figure 1,

Figures 3a to d show details of diagrammatic longitudinal sectional views of a number of electron guns,

Figure 4 shows the variation of the function $-\Delta V/E(z)$ for the electron guns as shown in Figures 3a to d,

Figures 5 and 6 again show details according to Figures 3a and 3c, respectively, showing a number of rays (electron paths) of the electron beam and with a number of equipotential lines,

Figures 7a and 7b show the measured intensity distribution in a spot obtained in a prior art cathode-ray tube, and

Figures 8a and b show the measured intensity distribution in a spot obtained in a cathode-ray tube made in accordance with the invention.

Figure 1 is a horizontal longitudinal sectional view of a cathode-ray tube for displaying coloured television pictures, hereinafter termed colour display tube. The colour display tube comprises a glass envelope 1 which is composed of a display

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window 2, a cone 3 and a neck 4. An electron gun system 5 is provided in the neck 4 which system comprises three electron guns 6, 7, 8 which generate three electron beams 9, 10 and 11, respectively, with their axes situated in one plane (the plane of the drawing). The axis of the central electron gun 7 coincides with the tube axis 12. The display window 2 comprises on its inside a plurality of triplets of phosphor lines. Each triplet comprises a line consisting of a blue-luminescing phosphor, a line consisting of a green-luminescing phosphor, and a line consisting of a red-luminescing phosphor. All triplets together constitute the display screen 13. The phosphor lines are substantially perpendicular to the plane of the drawing. Positioned in front of the display screen 13 is a shadow mask 14 in which a plurality of elongate apertures 15 are provided through which the electron beams 9, 10 and 11 pass which each impinge only upon phosphor lines of one colour. The three electron beams situated in one plane are deflected by a system of deflection coils 16. The electron gun system 5 of the illustrated colour display tube consists of three individual electron guns 6, 7 and 8. However, it is also possible to use the invention in a so-called integrated electron gun system, as described, for example, in the already mentioned published Netherlands Patent Application 7902868, in which the electron guns have a number of electrodes in common. Examples of other cathode-ray tubes made in accordance with the invention are colour display tubes in which phosphor dots are used instead of phosphor lines, monochromatic cathode-ray display tubes and camera tubes.

Figure 2 is a longitudinal sectional view through one of the electron guns as used in the cathode-ray tube shown in Figure 1. In the control grid 20 is present a cathode 21 having a heater element 22 in a cathode shaft 23, which shaft has an emissive surface opposite to the aperture 24 in the control grid 20. The cathode 21 is suspended in the control grid 20 so as to be electrically insulated therefrom.

The anode which is also the first lens electrode 25 constitutes, together with the second electrode 26, a pre-focusing lens in the operating display tube. The lens electrodes 26 and 27 together constitute the main focusing lens. Main focusing lenses consisting of more electrodes are also known. Such main electrode lenses can also be used in a cathode-ray tube made in accordance with the invention.

The cathode-ray tubes made in accordance with the invention may also use electron guns in which the beam is deflected near the cross-over, as is the case, for example, in United States Patent Specification 4291251 or in electron guns in which the beam is deflected in the main focusing lens.

Figures 3a to d show diagrammatically a detail of a longitudinal sectional view of a number of electron guns including the gun shown in Figure 2. The sectional views of the electrodes are shown only on one side of the Z axis. The location and the dimensions of the cathode 30, the control grid 31 and the first electrode 32 which is also the anode, are the same in all four figures 3a to d. The dimensions can be read from the scale division along the Z axis and the R axis. The voltages in Volts at the various electrodes are shown in Figures 3a to d.

Figure 3a is a detail of a sectional view of an electron gun in which the second lens electrode 33 comprises an aperture 34 having a diameter of 1.50 mm. The diameter of the aperture 35 in electrode 32 is 0.65 mm. The spacing between the first lens electrode 32 and the second lens electrode 33 is 0.8 mm. The electron gun corresponds substantially to an electron gun described in the said published Netherlands Patent Application 7902868.

Figure 3b is a detail of a sectional view of an electron gun which is substantially the same as the detail of Figure 3a. However, there is a difference which is that the diameter of an aperture 36 in the second lens electrode 37 is considerably smaller and is 0.65 mm.

Figure 3c is also a detail of a sectional view of an electron gun in which the diameter of the aperture 38 in the second lens electrode 39 is the same as the diameter of the aperture 36 in Figure 3b, but the spacing between the first lens electrode 32 and the second lens electrode 39 is only 0.4 mm.

Figure 3d is a detail of a sectional view of an electron gun in which an aperture 41 having a diameter of 0.65 mm is provided in the second lens electrode 40, but the distance between the first and second lens electrodes 32 and 40 is 1.5 mm.

Figure 4 shows the function $-\Delta V/E(z)$ in the curves A to D, respectively, for the situations shown in Figures 3a to 3d, respectively. For each of these situations, the minimum of said function indicated by the broken lines represents an effective spacing: S-eff. This minimum value depends on the electrode dimensions and the location of the lens electrodes. It has been found in practice that the diameter of the aperture in the second lens electrode must be smaller than twice the diameter of the aperture in the first lens electrode and the effective spacing S-eff must be smaller than 1 mm. In that case the edge rays of the electron beam immediately after the cross-over are bent inwardly considerably more than the remaining rays.

Figure 5 again shows the detail of Figure 3a but this time with a number of computed rays 50 (electron paths) of the electron beam. Moreover, a number of equipotential lines 51 are shown.

Figure 6 again shows the detail of the longitudinal sectional view of Figure 3c with a number of computed rays 60 (electron paths) of the electron beam and with a number of equipotential lines 61. Both in Figure 5 and in Figure 6, adjoining parts of the electron beam are shown one below the other.

In the electron gun shown in Figure 6 considerably more edge rays are bent further into the beam than in the Figure 5 electron gun.

5 Figures 7a and 7b show from two mutually perpendicular directions a measured intensity distribution in a spot on a display screen of a prior art electron gun. Figures 8a and 8b show in an analagous manner a measured intensity distribution in a spot of an electron gun used in a cathode-ray tube made in accordance with the invention. Comparison of Figures 7a 10 and 8a and Figures 7b and 8b shows that the spot quality of an electron gun used in the cathode-ray tube made in accordance with the invention is considerably better than that of a prior art electron gun.

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CLAIMS:

1. A cathode-ray tube comprising in an evacuated envelope means to generate at least one electron beam and to form a cross-over behind which, viewed in the direction of propagation of the electron beam, are provided successively an accelerating pre-focusing lens comprising a first and second lens electrode centred around an axis, and a main focusing lens comprising at least two lens electrodes, wherein the diameter of the aperture in the second lens electrode is smaller than twice the diameter of the aperture in the first lens electrode and the effective spacing S_{eff} between the first and the second lens electrodes is smaller than 1 mm, S_{eff} being defined as the minimum of the function

$$-\frac{\Delta V}{E(z)}, \text{ wherein}$$

ΔV is the voltage difference applied in use between the second and first lens electrodes and $E(z)$ is the electrical field strength existing in use between the first and second lens electrodes on the axis as a function of a place z on the axis.

2. A cathode-ray tube as claimed in Claim 1, wherein the means to generate an electron beam comprise a cathode, a control grid and an anode, the anode also forming the first lens electrode.

3. A cathode-ray tube as claimed in Claim 1 or 2, wherein the spacing between the second lens electrode and the first lens electrode is smaller than 0.8 mm.

4. A cathode-ray tube as claimed in Claim 1, 2 or 3, wherein the diameter of the aperture in the first lens electrode is smaller than 0.9 mm and the diameter of the aperture in the second lens electrode is smaller than 1.6 mm.

5. A cathode-ray tube as claimed in Claim 1, 2, 3 or 4, wherein the diameter of the aperture in the second lens electrode is equal to or substantially equal to the diameter of the aperture in the first lens electrode.

6. A cathode-ray tube as claimed in any one of the preceding Claims, wherein the spacing between the first and the second lens electrodes is equal to or substantially equal to 0.4 mm.



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7. A cathode-ray tube constructed and arranged to operate substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 6 and 8 of the accompanying drawings.

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