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(54) ELECTRON GUNS FOR USE IN CATHODE RAY TUBES

(71) We, HITACHI LTD., a corporation organised and existing under the laws of Japan, of 5-1, Marunouchi 1-chome, Chiyodaku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to unipotential electron guns and assemblies for use in cathode ray tubes.

Such electron guns are useful in monochromatic and color cathode ray tubes of television receiving sets. As is well known in the art, the envelope of a cathode ray tube of this type is constituted by a panel, a funnel and a neck. On the inner surface of the panel is formed a phosphor screen upon which an electron beam impinges to cause the phosphor screen to luminesce. Inside the neck is provided an electron gun including a plurality of electrodes which emits an electron beam of the desired intensity under the control of video signals. Typically, a color picture tube contains in its neck three electron guns for emitting three electron beams. Within the panel is supported a color selection electrode or a shadow mask having a plurality of apertures for passing the electron beams. These apertures have a predetermined configuration and are arranged in the form of a predetermined pattern. On the inner surface of the panel of a color picture tube is formed a phosphor screen containing phosphors for causing red, green and blue colour luminescences, these phosphors being arranged in a pattern which is determined by the arrangement of electron guns and the colour selection electrode apertures of the predetermined configuration.

The electron gun comprises an electron beam emitter which emits a controlled intensity electron beam under the control of an external control signal, for example a video signal, and a group of electrodes which constitutes a main electron lens for focusing the electron beam on the phosphor screen.

In a unipotential type electron gun the electrode group constituting the main lens comprises three tubular electrodes which are arranged coaxially with predetermined gaps therebetween. The same anode voltage is impressed upon the first and third electrodes and a suitable focusing voltage is impressed upon the intermediate electrode, these electrodes largely governing the focusing characteristics of the electron gun.

However, in prior art unipotential type electron guns, the length of the intermediate electrode is shorter than that of the first and third electrodes and the focusing voltage applied to the intermediate electrode is usually substantially zero. With such electron guns, there are defects in that the spherical aberration is large and the beam spot diameter is insufficiently small for a practical range of current.

The above description refers to defects of the unipotential type electron gun for use in a monochromatic cathode ray tube. The same defects are found when a unipotential type electron gun assembly is used in a color picture tube, comprising three electron guns each having a similar construction.

According to the present invention there is provided a cathode ray tube unipotential electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode, the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter not outside the range of from $4.0D$ to $5.4D$.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a longitudinal sectional view diagrammatically showing one example of a cathode ray tube to which an electron gun of this invention is applicable;

Fig. 2 is a longitudinal sectional view showing the outline of a prior art unipotential type electron gun;

Fig. 3 is a longitudinal sectional view showing the outline of one example of unipotential type electron gun embodying the invention;

Fig. 4A is a graph showing the relationship between the electrode length of a unipotential type electron gun and the focusing voltage;

Fig. 4B is a graph showing the relationship between the electrode length of a unipotential type electron gun and the beam spot diameter;

Fig. 5 is a side view, partly broken, showing the outline of one embodiment of this invention applied to an in-line type electron gun of a color picture tube;

Fig. 6A is a side view showing the outline of another embodiment of this invention as applied to a delta type electron gun of a color picture tube; and

Fig. 6B is a front view of Fig. 6A.

To aid better understanding of this invention, before describing preferred embodiments of this invention, the outline of a cathode ray tube in which the electron gun of this invention is to be incorporated and one example of a prior art unipotential type electron gun will firstly be described by referring to Figs. 1 and 2. As diagrammatically shown in Fig. 1, a cathode ray tube comprises an envelope including a panel or face plate 10, a funnel 11 and a neck 12. Inside the neck 12 is disposed an electron gun 13 adapted to emit an electron beam. A phosphor screen 15 is formed on the inner surface of the panel 10 for receiving an electron beam of a desired intensity which is emitted by the electron gun and controlled by an external control signal for causing the phosphor of the screen to luminesce at a desired brightness. In a color picture tube of a television receiving set, a color selection electrode 14 having a plurality of apertures for passing the electron beam is mounted close to the phosphor screen 15, and the phosphor screen is made up of phosphors for emitting three colours, whereby when irradiated by three electron beams emitted by an electron gun assembly including three electron guns, the phosphors emit red, green and blue lights as well known in the art.

As the electron gun 13, a unipotential type electron gun is frequently used because of a relatively simple construction of the elec-

trode group constituting the main lens. Fig. 2 diagrammatically shows one example of a prior art unipotential type electron gun for use in a monochromatic cathode ray tube. As shown, a cathode electrode 20 and first to fifth grid electrodes 21 through 25 each having the same inner diameter are coaxially supported by a supporting member, not shown, with suitable gaps therebetween. The cathode electrode 20, and the first and second grid electrodes 21 and 22 constitute an electron emission member which controls the intensity of the emitted electron beam when applied with such an external control signal as a video signal in a manner well known in the art. A group of three electrodes including the third to fifth grid electrodes 23, 24 and 25 constitutes a main lens. The fifth and third grid electrodes 25 and 23 on both sides are impressed with the same anode voltage V_a , while the intermediate fourth grid electrode 24 is supplied with a focusing voltage V_f , the dimensions of these electrodes greatly governing the focusing characteristic of the electron gun.

Apertures 21a and 22a of the first and second grid electrodes 21 and 22 are disposed to face the electron emitting surface of the cathode electrode 20 and the entrance aperture 23a of the third grid electrode 23 is disposed in coaxial relationship with apertures 21a and 22a. The exit aperture of the third grid electrode 23, the entrance and exit apertures of the fourth grid 24, and the entrance aperture of the fifth grid electrode 25 have the same diameter as the inner diameter of these tubular grid electrodes. The gap d_1 between the third and fourth grid electrodes 23 and 24 and the gap d_2 between the fourth and fifth grid electrodes 24 and 25 are necessary for constituting the main lens and usually have a length of less than 2mm, preferably 1mm. If these gaps are larger than 2mm, the external field adversely affects or disturbs the electric field produced by the main lens.

In the conventional unipotential type electron gun shown in Fig. 2, as the length of the fourth grid electrode 24 increases, the spherical aberration decreases while at the same time the focusing voltage V_f necessary to suitably focus the electron beam increases. We have made various experiments in which the lengths of the third and fourth grid electrodes 23 and 24 were varied variously.

The result of experiments made on one embodiment of the unipotential type electron gun of this invention will now be described with reference to Figs. 3, 4A and 4B. In Fig. 3, elements corresponding to those shown in Fig. 2 are designated by the same reference characters. For the sake of brevity, although sources of the focusing voltage and the anode voltage and the connections thereof are not shown, it should be understood

that they are identical to those shown in Fig. 2. The electron gun shown in Fig. 3 is different from that shown in Fig. 2 in that the fourth grid electrode 24 shown in Fig. 3 is longer than the fourth grid electrode shown in Fig. 2, and that the length of the third grid electrode 33 is selected to a value corresponding to the length of the fourth grid electrode 24. For the reason described above, again the gap lengths d_1 and d_2 are less than 2mm, preferably 1mm.

In the unipotential type electron gun shown in Fig. 3 as the length l_4 of the fourth grid electrode 34 increases, the spherical aberration decreases and such decrease reaches a limit when the length becomes 1.1 time the inner diameter D of the grid electrode. Within this limit, a small beam spot diameter was obtained for a certain value of beam current (intensity of the beam).

The relationship between the electrode length l_4 and the beam spot diameter was determined experimentally as shown by a graph shown in Fig. 4B in which the abscissa represents the total length in terms of multiple of the inner diameter D of the grid electrode which corresponds to the sum l_4 of the length l_3 of the third grid electrode 33, gap length d_1 , the length l_4 of the fourth grid electrode 34, and the gap length d_2 . A preferred value of the inner diameter D ranges from 3.5 to 20mm, and the length l_4 was selected to be $l_4 = 2.5D$ for $D = 5.5$ mm. Furthermore, $V_B = 20$ KV was used.

for controlling the material delivery valve As shown in Fig. 4B, for a large current of 4mA, the beam spot diameter becomes minimum at a total length $l_4 = 4.0D$, whereas at a small current of 0.1mA, the beam spot diameter decreases as the total length l_4 increases.

The graph shown in Fig. 4A shows the relationship between the focusing voltage and the total length l_4 in which the ordinate represents the ratio of the focusing voltage to the anode voltage and the abscissa shows the total length l_4 in terms of the multiple of the inner diameter D . Two straight lines show the relationship between l_4 and $V_F/V_B \times 100$ which gives the minimum beam spot diameter for constant currents of 4mA and 0.1mA, respectively. The minimum beam spot diameter varies depending upon the values of l_4 and $V_F/V_B \times 100$. More particularly, the minimum beam spot diameter is different for $l_4 = 3.0$ and $l_4 = 4.0$ so that the focusing voltage is adjusted such that the minimum but different beam spot diameters may be obtained for $l_4 = 3.0$ and $l_4 = 4.0$. The values of V_F thus obtained were plotted. As shown in Fig. 4A, near $l_4 = 5.0D$ a minimum beam spot diameter corresponding to 37% of V_B was obtained for both the large and small currents (this holds true for currents between these maximum and minimum

current values). When V_F deviates from 37%, the focusing voltage depends on the intensity of beam current and cannot be determined to a fixed value.

A circuit would be sophisticated which can provide an optimum value of beam spot diameter by varying the focusing voltage corresponding to the beam current and such a circuit is not practical. Accordingly, for the electron gun of the above described type, it is necessary to select a value of l_4 that can manifest satisfactory characteristic for a constant V_F . The reason that the focusing voltage V_F varies with the value of current is that the spreading of the electron beam about the axis and the affect of repulsion of the space charge caused by the value of the current elongate the focal length of the electron lens whereas increase in the spherical aberration shortens the focal length so that when these two effects become unbalanced the focusing voltage varies.

In the main electron lens of this invention, although the spherical aberration differs depending upon the length of the fourth grid electrode, the spherical aberration of the lens is governed so long as $l_4 \geq 1.1D$ by the spreading of the beam diameter in the main lens which, in turn, is determined by the length l_4 . Consequently, as the length l_4 increases the spreading of the beam in the main lens and hence the spherical aberration increases so long as $l_4 \geq 1.1D$. The practical range of l_4 is $4.0D \leq l_4 \leq 5.5D$. The length l_4 has a lower limit of the order of D for its capability of production. Although having been described hereinbefore that the first to fifth grid electrodes have the same inner diameter, it is not essential according to the invention that all the grid electrodes have the same inner diameter. The inner diameters of the first and second grid electrodes may be different from those of the third to fifth grid electrodes. Also, an experiment shows that the inner diameter of the fourth grid electrode may be $D \pm 0.3D$.

Accordingly, when the electron lens is constituted by grid electrodes having dimensions described above, the spherical aberration is reduced so that it is possible to obtain a beam spot having a small diameter with a fixed focusing voltage over the entire current range. Consequently, it is possible to decrease the beam spot diameter by about 20 to 30% as compared with the prior art electron gun.

Turning to Figs. 5, 6A and 6B, the invention will be described by way of unipotential type electron gun assemblies for use in color picture tubes. Especially, Fig. 5 shows one example of in-line type unipotential electron gun assembly and Figs. 6A and 6B show one example of delta type unipotential electron gun assembly.

As diagrammatically shown in Fig. 5, the in-line type unipotential electron gun assembly comprises three electron guns arranged in line in which first to fifth grid electrodes associated with respective three electron guns, that is, for red, blue and green colors are each assembled in the form of an integral electrode as designated by 51, 52, 53, 54 and 55. Typically, a deep cup-shaped electrode 53a and a shallow cup-shaped electrode 53b are combined to constitute an electrode for one electron gun. The array of these cup-shaped electrodes for the central electron gun is reversed with respect to that for electron guns on both sides so that electric fields for three electron guns do not interfere. The grid electrodes 51 to 55 together with cathode 50 are supported coaxially by supporting beams 56. Although not shown, an anode voltage is supplied to the third and fifth grid electrodes 53 and 55 and a focussing voltage is supplied to the fourth grid electrode 54 to thereby establish a main electron lens.

With this construction, when the length l_4 of the fourth grid electrode, that is, intermediate electrode is selected to be $l_4 \geq 1.1D$, where D is the inner diameter of opening of the third and fifth electrodes associated with one electron gun, the total length l_t is selected to be in a range of from $4.0D$ to $5.4D$, the same effect as in the embodiment of Fig. 3 can be obtained.

In Fig 6A and 6B, three electron guns are arranged in a delta configuration and first grid electrodes 61, second grid electrodes 62, an integral third grid electrode 63, an integral fourth grid electrode 64 and an integral fifth grid electrode 65 are supported by supporting beams 66. In this embodiment, the same effect as in the embodiment of Fig. 3 can be attained when $l_4 \geq 1.1D$ and $4.0D \leq l_t \leq 5.5D$ are satisfied.

WHAT WE CLAIM IS:—

1. A cathode ray tube unipotential electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode,

the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$; 65

2. An electron gun according to claim 1, wherein the length of the second, intermediate electrode is substantially $2.5D$.

3. An in-line unipotential electron gun assembly for use in a color picture tube, said assembly comprising three electron guns arranged in line, each electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode, the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$. 70 75 80 85 90

4. An electron gun assembly according to claim 3, wherein the length of the second, intermediate electrode is substantially $2.5D$. 95

5. A delta type unipotential electron gun assembly for use in a color picture tube, said assembly comprising three electron guns arranged in delta configuration, each electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode, the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$. 100 105 110 115 120

6. An electron gun assembly according to claim 5, wherein the length of the second, intermediate electrode is substantially $2.5D$.

7. An electron gun substantially as



As diagrammatically shown in Fig. 5, the in-line type unipotential electron gun assembly comprises three electron guns arranged in line in which first to fifth grid electrodes associated with respective three electron guns, that is, for red, blue and green colors are each assembled in the form of an integral electrode as designated by 51, 52, 53, 54 and 55. Typically, a deep cup-shaped electrode 53a and a shallow cup-shaped electrode 53b are combined to constitute an electrode for one electron gun. The array of these cup-shaped electrodes for the central electron gun is reversed with respect to that for electron guns on both sides so that electric fields for three electron guns do not interfere. The grid electrodes 51 to 55 together with cathode 50 are supported coaxially by supporting beams 56. Although not shown, an anode voltage is supplied to the third and fifth grid electrodes 53 and 55 and a focussing voltage is supplied to the fourth grid electrode 54 to thereby establish a main electron lens.

With this construction, when the length l_4 of the fourth grid electrode, that is, intermediate electrode is selected to be $l_4 \geq 1.1D$, where D is the inner diameter of opening of the third and fifth electrodes associated with one electron gun, the total length l_L is selected to be in a range of from $4.0D$ to $5.4D$, the same effect as in the embodiment of Fig. 3 can be obtained.

In Fig 6A and 6B, three electron guns are arranged in a delta configuration and first grid electrodes 61, second grid electrodes 62, an integral third grid electrode 63, an integral fourth grid electrode 64 and an integral fifth grid electrode 65 are supported by supporting beams 66. In this embodiment, the same effect as in the embodiment of Fig. 3 can be attained when $l_4 \geq 1.1D$ and $4.0D \leq l_L \leq 5.5D$ are satisfied.

WHAT WE CLAIM IS:—

1. A cathode ray tube unipotential electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode,

the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$.

2. An electron gun according to claim 1, wherein the length of the second, intermediate electrode is substantially $2.5D$.

3. An in-line unipotential electron gun assembly for use in a color picture tube, said assembly comprising three electron guns arranged in line, each electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode, the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$.

4. An electron gun assembly according to claim 3, wherein the length of the second, intermediate electrode is substantially $2.5D$.

5. A delta type unipotential electron gun assembly for use in a color picture tube, said assembly comprising three electron guns arranged in delta configuration, each electron gun comprising an electron beam emitter, means for controlling the electron beam intensity, a main electron lens adapted to focus the electron beam and comprising first, second and third tubular electrodes which are disposed coaxially with axial gaps therebetween, means for impressing an anode voltage upon the first and third electrodes and for impressing a fixed focusing voltage upon the second, intermediate electrode, wherein the axial length of the second electrode is not less than $1.1D$, where D is the inner diameter of the first and third electrodes, and wherein the sum of the length of the first electrode nearer the emitter, the length of the second electrode, the gap length therebetween, and the gap length between the second electrode and the third electrode further from the emitter is not outside the range of from $4.0D$ to $5.4D$.

6. An electron gun assembly according to claim 5, wherein the length of the second, intermediate electrode is substantially $2.5D$.

7. An electron gun substantially as

described herein with reference to Fig. 3 of the accompanying drawings.

8. An electron gun assembly substantially as described herein with reference to Fig. 5,
5 or Figs. 6A and 6B, of the accompanying drawings.

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