

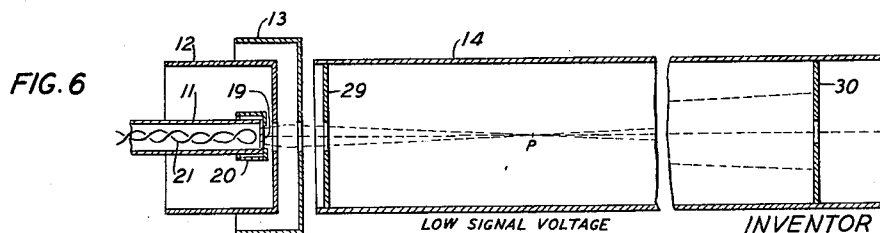
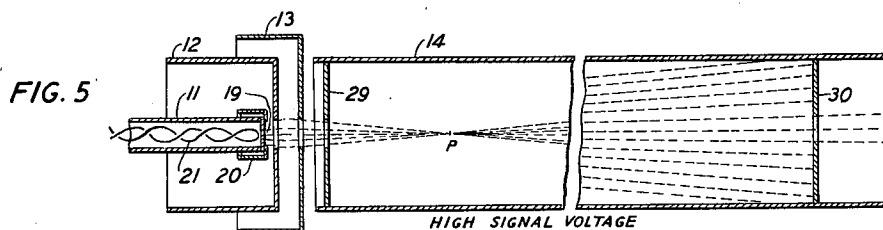
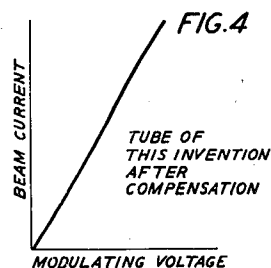
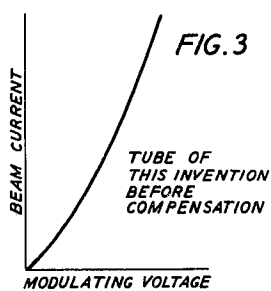
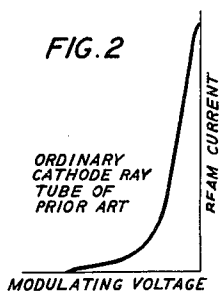
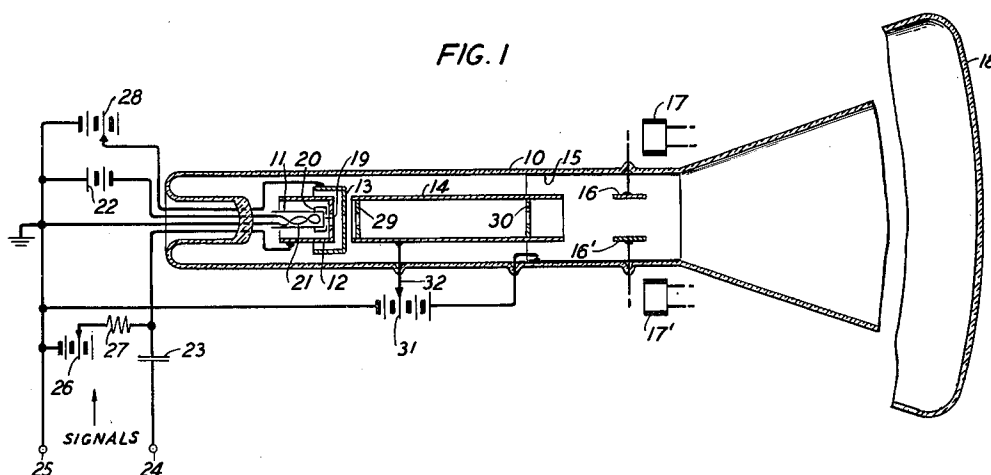
Oct. 28, 1941.

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2,260,313

CATHODE RAY TUBE

Filed Feb. 8, 1939



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2,260,313

CATHODE RAY TUBE

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Application February 8, 1939, Serial No. 255,226

15 Claims. (Cl. 250—27)

This application relates to cathode ray tubes and more specifically to electron optical arrangements for said cathode ray tubes.

It is an object of this invention to provide a novel method of and apparatus for modulating an electron beam in a cathode ray tube.

In many present-day cathode ray tubes for television and the like, a Wehnelt cylinder or disc is used to bring the electron to an initial focus, and also to modulate the intensity of the beam. The Wehnelt element is biased negatively with respect to the cathode to bring the electrons to a focus, and, in modulating the electron current, it acts very much like the control grid in an amplifier tube. The characteristic curve of beam current versus modulating voltage in such a cathode ray tube is similar to the characteristic curve of an amplifier tube; it is not linear and tails off slowly at its lower end. This lack of linearity distorts the reproduction of shades in a television image, and the tailing off at the lower end is particularly objectionable for it results in an almost complete loss of detail in the darker portions of an image.

It has been discovered that these defects may to a large extent be corrected by modulating the beam current by means of an anode immediately adjacent the cathode. In such an arrangement the current drawn from the cathode decreases with the anode voltage, and ceases abruptly at zero voltage so that there is no tailing off in the usual sense. The current drawn from the cathode does, however, vary as the three halves power of the modulating voltage, but this lack of linearity is more or less corrected by introducing a variation in the angular aperture of the electron lens system of this invention.

It is another object of this invention to provide a novel electron lens system in which modulating voltages are applied to a member which is adjacent and positively biased with respect to the cathode of the system.

In accordance with the invention, there is provided, by way of example, a cathode ray device comprising an evacuated envelope enclosing a novel electrode assembly and a screen or target. This assembly comprises, in order, going towards the screen or target, an equipotential cathode constituting a plane source of electrons, a modulating or control element or anode adjacent the cathode, an auxiliary apertured electrode which is placed at a potential which is slightly negative with respect to the modulating anode, a high potential tubular anode having an apertured diaphragm near the end toward the cathode and

another near the end remote from the cathode, a cylindrical final anode (which may comprise a coating on the inside walls of the enclosure), and deflecting elements to cause the beam of electrons to move over the surface of the screen or target. The current density drawn from the cathode varies as the three halves power of the modulating voltage but this non-linearity is compensated for by the shifting in the divergence of focus of the beam, which change in focus changes the number of electrons that passes through the aperture in the diaphragm at the remote end of the tubular anode. With proper dimensioning and spacing of the electrode elements, this change in divergence may be used to correct for the non-linearity in the current density drawn from the cathode, and the beam current made to vary almost linearly with the modulating voltage. With this method of modulation the current can be made to cease abruptly at zero potential.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof, in which:

Fig. 1 is a schematic diagram of a cathode ray tube and some of its associated circuits used to illustrate the invention; and

Figs. 2 to 6, inclusive, are graphical and diagrammatic representations used to explain the operation of the invention.

Referring more particularly to the drawing, Fig. 1 shows, by way of example, a cathode ray tube containing an electrode assembly making use of positive modulation. The cathode ray device comprises an evacuated envelope 10 enclosing a cathode 11, a modulating or control anode 12, an auxiliary electrode 13, a second anode 14, a third anode comprising a conducting coating 15 on the inside walls of the enclosure 10, a pair of deflecting plates 16, 16' and a fluorescent screen or target 18. Outside the container is a pair of deflecting coils 17, 17'.

The cathode 11 has a flat end 19 which is oxide coated and constitutes a plane, equipotential source of electrons. After the end of the cathode is coated, a metal sleeve 20 is put over it to prevent any flow of current from the side walls of the cathode 11 to the anode 12. The sleeve 20 may be either flush with the end of the cathode, or may project slightly beyond the end thereof to reduce still further any flow of current to the modulating or control anode 12. The cathode is heated by a heater member 21 receiving current from the source 22. The modulating or control

anode 12 is an apertured disc which receives control voltage through coupling condenser 23 from signals applied between the terminals 24 and 25, the source of potential 26 and the resistance 27 being used to apply positive bias to the control anode 12 with respect to the cathode 11.

Proceeding along the axis of the tube towards the fluorescent screen or target 18, the control anode 12 is followed by an auxiliary electrode 13 which comprises an apertured disc. This electrode is placed at a potential which is not very far from zero (cathode) potential by means of the source 28. This potential may be slightly above zero or slightly below zero in various cases depending on the geometry of the particular electron lens system.

The electrons pass through the aperture in the auxiliary electrode 13 into the high potential tubular anode 14 having two apertured diaphragms 29 and 30 at opposite ends thereof. This anode is placed at a high potential with respect to the cathode 11 by means of the source 31 through an inner tap 32.

As the electrons pass through the aperture in the diaphragm 30 they come into a region receiving its electric field from a high potential coating 15 of suitable conducting material such as, for example, aquadag, which receives its potential from source 31. It is placed at a high positive potential with respect to the tubular anode 14. While the beam is in this region, it is caused to scan every elemental area of the fluorescent screen 18 in turn by means of deflecting signals respectively applied between the deflecting plates 16, 16' and passed through the deflecting coils 17, 17'. Any suitable electrostatic and electromagnetic sweep circuits of the proper frequency may be used in connection with the deflecting plates and deflecting coils. If desired, two sets of plates or two sets of coils may be used instead of one set of each.

The electron lens action of the various electrode elements will now be described. When the modulating anode 12 has a positive potential applied thereto, electrons are drawn from the cathode in the form of a diverging beam. (See Figs. 5 and 6 which show the approximate boundaries of the beam in its path through the electron lens, the region between the boundaries in Fig. 5 being filled with dotted lines to indicate greater beam density than in Fig. 6.) This beam tends to become converging as it passes through the aperture in the auxiliary electrode 13 due to the negative or retarding potential applied thereto with respect to the bias or average potential of the modulating anode 12. The convergence of the beam is further increased as it passes through the aperture in the diaphragm 29 and the beam comes to a focus at a point P somewhere between the diaphragms 29 and 30. Thus the combined lens system immediately in front of the cathode is equivalent to a single short focus lens; and, since the electrons leave the cathode normal to its surface, they are brought to focus in a small spot at P. An image of this spot is projected on the screen by the positive lens at the end of the tube 14 where it projects into the tubular or cylindrical anode formed by the coating 15 on the inside of the glass envelope 10.

The initial electron velocities and various imperfections in the lenses spread the focal point P out along the axis, and for this reason only the central portion of the beam is used for projecting a small spot on the screen. The periphery of

the beam is cut off by the apertured diaphragm 30 which also serves another purpose which will be considered below.

As the potential of the modulating anode 12 is lowered, the current density drawn from the cathode decreases and finally ceases abruptly with no tailing off, provided that the auxiliary anode 13 is at approximately zero potential, so that there is no appreciable penetration of electric fields through the aperture of the modulating anode 12. In order, however, that the lenses at the auxiliary electrode 13 be not too short in focal length, the plane of its aperture should be slightly positive with respect to the cathode. Penetration of the field from the high potential anode 14 makes this plane more or less positive, depending on the thickness of the auxiliary disc and the diameter of the aperture. To secure the most favorable voltage in the plane of the aperture, the auxiliary electrode 13 may require a small bias with respect to the cathode, and this bias may be either positive or negative depending on the dimensions of the electrode. When the bias has an appreciable value, the beam may cut off at a voltage slightly different from zero. This is of no particular disadvantage in the operation of the tube.

Referring now to Figs. 2, 3 and 4, three curves are shown of beam current versus modulating voltage. In Fig. 2 is shown the characteristic curve of the ordinary present-day cathode ray tube employing a Wehnelt cylinder biased negatively with respect to the cathode. It will be noted that this characteristic curve is similar to the characteristic curve of an amplifier tube; it is not linear and tails off slowly at its lower end, this lack of linearity distorting the reproductions of shades in a television image, and the tailing off at the lower end being particularly objectionable for it results in almost complete loss of detail in the darker portions of an image. Fig. 3 shows the characteristic curve of beam current versus modulating voltage that would result from positive modulation without any correction or compensating caused by the limiting action of the aperture in the diaphragm 30. This curve shows that the current density drawn from the cathode varies as the three halves power of the modulating voltage. This non-linearity, which would also appear in the beam current (assuming there is no correction at the apertured diaphragm 30) is more or less corrected by causing the motion of the focal point P to affect the number of electrons which pass out into the beam. As the modulating voltage is decreased, the focal length of the combined lens system increases and the focal point P moves towards the diaphragm 30 as shown in Figs. 5 and 6, Fig. 5 representing the situation where a relatively high positive signal voltage is applied to the anode 12 and Fig. 6 where the anode voltage is decreased to a relatively low value. The intensity of the beams in Figs. 5 and 6 is represented by the distance between the dotted lines representing the beam. As shown in Fig. 5, the electron beam leaves the point P with an increased divergence and thus a smaller percentage of the electrons in the anode 14 passes out through the aperture in the diaphragm 30 than in the case of the smaller beam intensity shown in Fig. 6. In Fig. 6 there are fewer electrons in the beam within the anode 14 but a greater percentage of them passes through the aperture in the diaphragm 28. With proper dimensioning and spacing of the elec-

trodes, this change in divergence can be made to more or less correct for the non-linearity in the current density drawn from the cathode; and the beam current made to vary almost linearly with the modulating voltage as shown in the characteristic curve of beam current versus modulating voltage in Fig. 4. By proper proportioning various degrees of correction can be obtained.

It will be appreciated that the dimensions of the electrode system are more or less critical although some of them may vary within reasonable limits. As an example of the dimensions of a practical electrode arrangement, the following dimensions are given. The diameter of the cathode 11 is $\frac{1}{4}$ of an inch, the inside diameter of the modulating anode 12 and the tubular anode 14 is $\frac{3}{8}$ of an inch; the spacing between the end of the cathode 11 and the auxiliary electrode 12 is $\frac{1}{32}$ of an inch, the spacing between the modulating electrode 12 and the auxiliary electrode 13 is $\frac{3}{64}$ of an inch, the spacing between the auxiliary electrode 13 and the diaphragm 29 of the anode 14 is $\frac{3}{64}$ of an inch, the spacing between the diaphragm 30 and the far end (from the cathode) of the tubular anode 14 is $2\frac{1}{2}$ inches and the distance of the apertured diaphragm 30 from the far end of the tubular anode 14 is $\frac{1}{8}$ of an inch; the aperture in the modulating electrode 12 is $\frac{1}{8}$ of an inch in diameter, the aperture in the modulating electrode 13 is $\frac{7}{128}$ of an inch, the aperture in the diaphragm 29 is $\frac{1}{8}$ of an inch and the aperture in the diaphragm 30 is $\frac{1}{8}$ of an inch. The cap 20 extends out over the surface 19 of the cathode 11 by $\frac{1}{128}$ of an inch. The bias on the modulating anode 12 is made about 25 volts positive, the signal varying between approximately -25 volts to +25 volts; the potential of the auxiliary electrode 13 is made positive by a small amount which is less than 25 volts; the potential of the anode 14 is made 1000 volts and the potential of the conducting coating 15 is made about 3000 volts. If the direct current component is included in the modulating signal, the bias on the modulating anode 12 may be varied depending on the value of this direct current component. If the component is large, the bias may be omitted or even made negative. The important thing is that the direct current potential of the anode 12 be positive with respect to the cathode.

Various modifications may be made in the embodiment of the invention as above disclosed, the scope of the invention being indicated by the appended claims.

What is claimed is:

1. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for varying the potential of said conducting element relative to that of said cathode, additional means cooperating with said cathode and said element to cause the major portion of the emitted electrons to take the form of a beam which is diverging when it reaches said plane and later converging to a focus on said axis at a point dependent upon the potential of said conducting element and also to cause the number of emitted electrons to vary in the

same sense with the variations in said potential, and means for utilizing the change in position of focus to vary the number of electrons reaching said target.

2. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for varying the potential of said conducting element relative to that of said cathode, additional means cooperating with said cathode and said element to cause the major portion of the emitted electrons to take the form of a beam which is diverging when it reaches said plane and later converging to a focus on said axis at a point dependent upon the potential of said conducting element and also to cause the number of emitted electrons to vary in the same sense with the variations in said potential, said additional means comprising an electrode maintained at a steady potential not greatly different from that of said cathode, and an anode nearer said target than is said last-mentioned electrode maintained at a potential higher than the maximum potential impressed upon said conducting element, and means including an apertured diaphragm in said anode for utilizing the change in position of focus to vary the number of electrons reaching said target.

3. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for varying the potential of said conducting element relative to that of said cathode, additional means cooperating with said cathode and said element to cause the major portion of the emitted electrons to take the form of a beam which is diverging when it reaches said plane and later converging to a focus on said axis at a point dependent upon the potential of said element and also to cause the number of emitted electrons to vary in the same sense with the variations in said potential, said additional means comprising an electrode assembly to provide an electron retarding field in the spacing into which said diverging beam is projected, and means for utilizing the change in position of focus to vary the number of electrons reaching said target.

4. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for varying the potential of said conducting element relative to that of said cathode, additional means cooperating with said cathode and said element to cause the major portion of the emitted electrons to take the form of a beam which is diverging when it reaches said plane

and later converging to a focus on said axis at a point dependent upon the potential of said element and also to cause the number of emitted electrons to vary in the same sense with the variations in said potential, and an electrode having a small aperture in the path of said beam, the dimensions of said aperture relative to those of the different cross-sections of said beam in the plane of the aperture as the focal point moves being such that the number of electrons passing through said aperture will vary with variations in the position of said focal point.

5. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for biasing said conducting element to a potential which is positive with respect to that of said cathode, means for varying the potential of said conducting element relative to that of said cathode, and electrode means positioned adjacent said conducting element and on the side thereof toward said target and effectively surrounding a line connecting the center of said cathode with that of the target and symmetrical therewith and cooperating with said conducting element to set up a field adjacent the latter to cause, in cooperation with said cathode and said element by reason of the field therebetween, the emission of electrons from said cathode to cease when the potential of said conducting element is reduced to a value which is at least substantially equal to that of said cathode.

6. In a cathode ray device, a cathode, a target, means for creating a diverging electrostatic field near said cathode, means for varying the strength of said field in accordance with signals, and means for creating a converging field in a region farther along the axis of the device for forming the electrons of said cathode into substantially a point, said point moving along the axis of said device as the strength of said diverging field is varied, and means including an apertured diaphragm for variably intercepting portions of said beam in accordance with the signals applied to said diverging field creating means, said diaphragm being between said focal point and said target.

7. In a cathode ray device, an evacuated envelope enclosing a cathode, an anode adjacent said cathode, a second anode, means for biasing said first anode to a positive potential with respect to said cathode, means for placing the second anode at a much higher positive potential than said first anode, means for shielding said cathode from the potential of said second anode, means for applying modulating voltage between said first anode and said cathode from a range of voltages such that the number of electrons emitted from said cathode is varied in accordance with some positive power of the modulating voltage, the positive bias on said first anode being of such value as to ensure this action.

8. In a cathode ray device, a cathode, an anode adjacent said cathode, a second anode, means for biasing said first anode to a positive potential with respect to said cathode, means for placing said second anode at a much higher positive potential than said first anode, means for shielding said cathode from the potential of said sec-

ond anode, means for applying modulating voltage between said first anode and said cathode from a range of voltages such that the number of electrons emitted from said cathode is increased with increase in modulating voltage, the positive bias of said first anode being of such value as to ensure this action, and means including an apertured diaphragm in said second anode for variably intercepting portions of said beam in accordance with the intensity of the modulating voltage.

9. In a cathode ray device, a cathode, a target, means for creating a diverging electrostatic field near said cathode, means for varying the strength of said field in accordance with signals, and means for creating a converging field in a region farther along the axis of the device for forming the electrons of said cathode into substantially a point, said point moving along the axis of said device as the strength of said diverging field is varied, means including an apertured diaphragm between said focal point and said target for variably intercepting portions of said beam in accordance with the signals applied to said diverging field creating means, and means for focussing an electron image of said aperture on said screen.

10. An electron gun arrangement comprising an equi-potential cathode having one end oxide coated, a cap around a portion of said cathode, said cap projecting slightly beyond the oxide coated end of said cathode, an apertured diaphragm parallel to and closely adjacent the oxide coated end of said cathode, a second apertured diaphragm parallel to said first apertured diaphragm and farther removed from said cathode than said first diaphragm, a tubular anode symmetrically arranged with respect to and surrounding a portion of the axis of said gun farther remote from said cathode than said second apertured diaphragm, said tubular member comprising two apertured diaphragms, a metallic cylindrical member symmetrically arranged with respect to said axis and generally surrounding a portion of said axis the center of which is farther removed from the cathode than the center of the portion of the axis surrounded by said tubular anode, means for placing said first apertured diaphragm at a positive potential with respect to said cathode, means for placing said second apertured diaphragm at a potential which is approximately that of said cathode but which is negative with respect to the potential of said first apertured diaphragm, means for placing said tubular anode at a potential which is highly positive with respect to said cathode and said first apertured diaphragm, means for placing said cylindrical member at a potential which is highly positive with respect to that of said tubular anode, and means for applying modulating voltages between said first apertured diaphragm and said cathode.

11. An electron gun comprising a cathode for generating a stream of electrons, a modulating anode adjacent said cathode, an auxiliary electrode adjacent said anode, a tubular anode having an apertured diaphragm therein in the portion thereof remote from said cathode, said anodes and said auxiliary electrode cooperating to focus the electrons to a point on the axis of said electron gun near the plane of said apertured diaphragm, and means for applying signals between said cathode and modulating anode to simultaneously cause the number of emitted electrons to

vary in the same sense as the variations in potential of said signals and change the focus of said electrons with respect to said diaphragm.

12. An electron gun comprising a cathode for generating a stream of electrons, a positively biased modulating anode adjacent said cathode, means for applying signals to said modulating anode to vary the emission from said cathode as the three halves power of said modulating voltage, and means for correcting in part at least for the departure from linearity in the characteristic curve of emission from the cathode versus modulating voltage.

13. The method of controlling electrons emitted from a cathode which comprises the steps of varying the number of electrons emitted by the cathode in accordance with a varying voltage, the number emitted increasing substantially as the three halves power of the varying voltage, forming the major portion, at least, of the emitted electrons into a beam, and selectively utilizing a portion only of said beam, said portion increasing with increase of said varying voltage but at a different rate which causes the selected beam to have an intensity which varies more nearly directly proportionally to the variations in said voltage than does the number of electrons in said beam prior to said selection.

14. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for biasing said conducting element to a potential which is positive with respect to that of said cathode, means for applying modulating voltage to said conducting element to vary the potential thereof relative to that of said cathode between a lower and an upper limit of potential, the conducting element when at the lower limit of potential being substantially at the potential of the cathode and when at the upper limit being at a potential which is at least as positive as the potential of said conducting element when only the biasing voltage is applied thereto, and electrode means positioned adjacent said conducting element and on the side thereof toward said target and effectively surrounding a

line connecting the center of said cathode with that of the target and symmetrical therewith for cooperating with said cathode and said element to cause the emission of electrons from said cathode to cease when the potential of said conducting element is reduced to a value which is substantially equal to that of said cathode, said electrode means comprising an electrode element which is placed at a potential within a range having as a lower limit a potential which is slightly negative with respect to that of said cathode and having as an upper limit a potential which is approximately equal to that of the conducting element when only the biasing voltage is applied thereto.

15. A cathode ray tube device comprising an electron emitting cathode, a target, a conducting element having an annular portion symmetrically encircling the tube axis which passes through the center of the emitting portion of the cathode and extends to the target, said annular portion extending on the side towards said target to a plane perpendicular to said axis between said cathode and target and relatively close to the former, means for biasing said conducting element to a potential which is positive with respect to the potential of said cathode, means for varying the potential of said conducting element relative to that of said cathode, and electrode means effectively surrounding a line connecting the center of said cathode to that of the target and symmetrical therewith and cooperating with said conducting element to set up a field adjacent the latter to cause, in cooperation with said cathode and said element by reason of the field therebetween, the emission of electrons from said cathode to cease when the potential of said conducting element is reduced to a value which is substantially equal to that of said cathode, said electrode means comprising a first additional electrode element adjacent said conducting element and a second additional electrode element adjacent said first additional electrode element and between said first additional electrode element and said target, said additional electrode elements cooperating with said cathode and said conducting element to form a beam of electrons which converges toward a point on the side of said first additional electrode element remote from said cathode.

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