

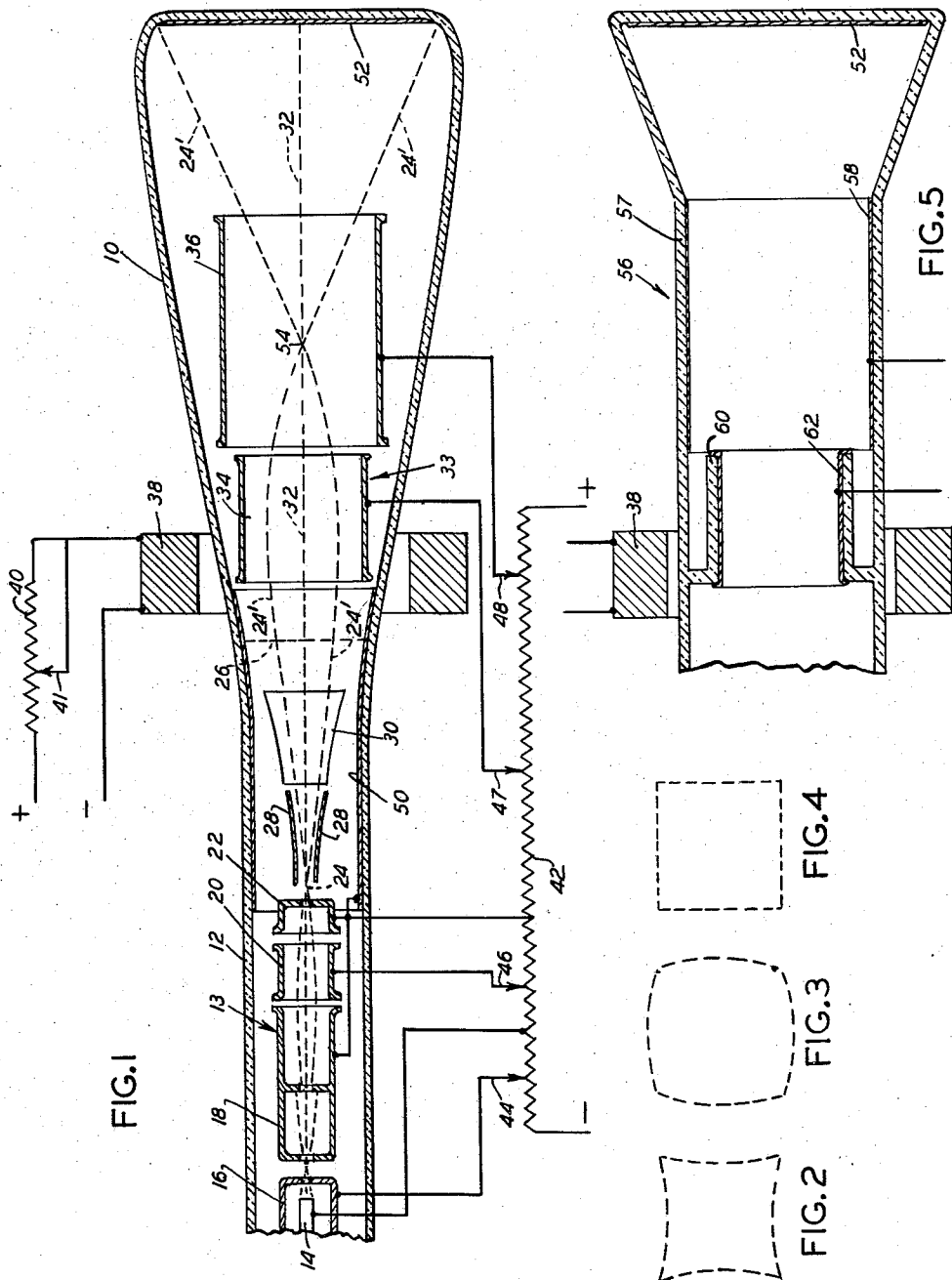
Feb. 27, 1962

L. FRENKEL

3,023,336

CATHODE RAY TUBE HAVING POST ACCELERATION

Filed Oct. 25, 1957



INVENTOR.
LOTHAR FRENKEL
BY
BUCKHORN, CHEATHAM & BLORE

ATTORNEYS

1

3,023,336

CATHODE RAY TUBE HAVING POST
ACCELERATION

Lothar Frenkel, Portland, Oreg., assignor to Tektronix,
Inc., Portland, Oreg., a corporation of Oregon
Filed Oct. 25, 1957, Ser. No. 692,483
8 Claims. (Cl. 313-78)

This invention relates to a cathode ray tube having post acceleration and more particularly to such a cathode ray tube in which a brighter image of any desired size within wide limits may be produced without causing spherical aberration in the image and in which the deflection sensitivity may be made very high.

In cathode ray tubes particularly suitable for oscilloscopes, it is desirable to produce a sharply focused image on the screen of the tube of substantial size and brightness. With all other factors constant, the brightness of the image depends upon the velocity with which the electrons of the electron beams strike the screen of the tube. Increasing the velocity of the electrons in the beam before deflection of the beam in order to brighten the image, increases the deflection energy required to produce an image of a given size to thus reduce the deflection sensitivity of the tube. It is also possible to increase the velocity of the electrons in the beam after deflection of the beam. Previously known structures for accomplishing this have, however, either resulted in a marked reduction in deflection sensitivity of the tube or have produced excessive spherical aberration in the resulting image on the screen of the tube.

In accordance with the present invention, the electrons in the beam are accelerated after deflection of the beam but such acceleration is accomplished by the combination of an electrostatic electron accelerating and converging lens with a magnetic converging lens, which combination of lenses has sufficient converging action to cause the deflected beam to cross the path of an undeflected beam and produce a reversed image, such path being referred to in this application as the beam axis of the tube. The electrostatic lens is thus of the type which accelerates the electrons in the beam and also causes convergence thereof so as to bend the deflected beam toward the beam axis. Electrostatic lenses of this type, in general, produce substantial spherical aberration in the image. This is particularly true when such lens is employed for electron acceleration after deflection of the beam so as to operate with a large effective aperture. There is usually a critical point in the operating characteristic of such a lens at which substantially no spherical aberration is produced. Operating at such point, however, restricts the image on the screen of the tube to a fixed size for a given value of beam deflection. Such a lens can also be operated under conditions in which it produces spherical aberration of the "pincushion" type and the electrostatic lens of the present invention is operated under such conditions.

Magnetic beam converging lenses, in general, produce spherical aberration of the "barrel type." By employing a magnetic converging lens position to bend the deflected beam so as to also operate at a large effective aperture in combination with the electrostatic electron accelerating and converging lens discussed above, the two spherical aberration effects can be made to compensate for each other and the combined action of the two lenses can be employed to cause the deflected beam to cross the beam axis and produce an inverted image without spherical aberration. By bringing the electrons in the beam to a focus in a focal plane prior to their entrance into the lens system, the image formed at such focal plane can be projected in sharp detail upon the screen of the tube by the lens system of the present invention. Because of the acceleration effect of the lens system, the electrons strike

2

the screen with greater velocity and the image is brighter for an image of given size than would be the case without the electron accelerating and converging lens combination of the present invention. Also, it is possible to vary the size of the image on the screen to either produce a smaller image or a larger image than that which would be produced by a given initial deflection in the absence of the electron accelerating and converging lens combination of the present invention. It follows that a brightened image of the same size as that produced without such lens combination may be produced. Within limits a larger or magnified image can be made brighter than the image produced without the lens combination of the present invention. Thus, by adjusting both the magnetic lens and the electrostatic lens, images of any size within wide limits and of increased brightness may be produced on the screen of the cathode ray tube for a given value of deflection of the beam and without spherical aberration. With images of the larger size, the deflection sensitivity becomes very large.

It is therefore an object of the invention to provide an improved cathode ray tube in which post acceleration of the electrons in the beam is employed to produce a brighter image without restricting the size of the image on the screen or producing spherical aberration in such image.

Another object of the invention is to provide a cathode ray tube in which a combination of an electrostatic electron accelerating and converging lens with a magnetic converging lens is employed to produce either a brighter image or magnified image, or both, without decreasing the deflection sensitivity of the tube or distorting the image.

A further object of the invention is to provide a cathode ray tube for oscilloscopes in which the image produced by the deflection of a beam is brought to a focus at a focal plane intermediate the length of the tube and a post electron accelerating and converging lens system is employed to project such image upon the screen of a cathode ray tube while producing acceleration of the electrons in the deflected beam and enabling adjustment of the size of the image upon the screen and also preventing any substantial spherical aberration.

A still further object of the invention is to provide an improved cathode ray tube for oscilloscopes in which the image projected upon the screen of such tube has its brightness increased without producing spherical aberration of the image and in which the size of such image can be adjusted independently of the initial deflection of the beam.

Other objects and advantages of the invention will appear in the following description of preferred embodiments thereof shown in the attached drawings of which:

FIG. 1 is a partial diagrammatic vertical section through the cathode ray tube in accordance with the present invention, showing diagrammatically a portion of the associated circuit;

FIG. 2 is a diagrammatic view illustrating the type of spherical aberration which may be produced by an electrostatic electron accelerating and converging lens;

FIG. 3 is a view similar to FIG. 2 illustrating the type of spherical aberration produced by a magnetic electron converging lens;

FIG. 4 is a view similar to FIG. 2 illustrating the type of undistorted image which can be produced on the screen of a cathode ray tube by a combination of the two effects of FIGS. 2 and 3; and

FIG. 5 is a view similar to FIG. 1 showing a modified type of tube.

Referring more particularly to the drawings, FIG. 1 shows a cathode ray tube including a glass envelope 10 having a neck portion 12 in which is positioned an electron gun 13. The electron gun includes a cathode 14, a control grid 16, a pre-acceleration grid 18, a first or focusing anode 20 and an accelerating anode 22. The electron

gun illustrated is of the general type known as a zero current first anode electron gun. Such a gun is particularly suitable for employment with tubes of the present invention but any other known or suitable type of electron gun can be employed. The electron gun should be capable of producing a narrow beam of electrons which may be focused upon a focal plane indicated by a dash-dot line 26 at a position intermediate the length of the glass envelope 10. The beam 24 may be vertically deflected by a pair of vertical deflection plates 28 positioned adjacent the electron gun 13 and having deflection voltages applied thereto by suitable conductors (not shown). The beam may also be horizontally deflected by a pair of horizontal deflection plates 30 positioned between the vertical deflection plates and the focal plane 26 and supplied with horizontal deflection or sweep voltages through suitable conductors (not shown). In the absence of deflection of the beam, such beam will follow a beam axis indicated by the dotted line 32. The limits of vertical deflection of the beam are indicated by the dotted lines 24', such dotted lines defining the vertical extent in FIG. 1 through which the deflected beam 24 may travel rather than the boundary of a single beam of electrons. It will be apparent that similar limits of horizontal deflection can be shown in the horizontal plane so that an image is produced on the focal plane 26.

The deflected beam 24, after passing through the pairs of deflection plates 28 and 30 and the focal plane 26, passes through an electrostatic accelerating and converging lens 33 including a first open-ended cylindrical element 34 and a second open-ended cylindrical element 36 of greater internal diameter and greater length than the element 34. The two cylindrical elements are positioned so as to be concentric with each other and the element 36 is positioned adjacent the element 34 but further along the beam than the element 34. The elements 34 and 36 are of conducting material and are connected to points of increasingly higher positive potential with respect to the accelerating anode 22 of the electron gun. Such elements constitute a known type of electron accelerating and converging lens of the electrostatic type.

Positioned adjacent the element 34 and preferably exteriorly of the tube so as to surround the envelope 10 is a magnetic converging lens in the form of a coil 38 which is connected to a source of current through a resistor 40 engaged by an adjustable contact 41 to enable adjustment of the converging lens action of the coil 38. The coil 38 is preferably concentric with the elements 34 and 36 and its most effective position along the tube will usually be found to be between the focal plane 26 and the element 36 of the electrostatic lens 33.

All of the various elements in the envelope 10, including the elements of the electron gun 13, the deflection plates 28 and 30 and the elements 34 and 36 of the electrostatic accelerating and converging lens 33 are shown without their supporting elements for simplicity and clearness, and it will be understood that the required supporting elements may be of any known or suitable type and that the tube will be supplied with a suitable base. Also, the various elements of the electron gun and electrostatic and accelerating converging lens are shown as being connected to a single resistor 42 with variable contacts 44, 46, 47 and 48 thereon to provide for varying the bias on the control grid 16, the focusing voltage applied to the focusing anode 20 and the voltage applied to the elements 34 and 36 of the electrostatic lens assembly, respectively, but it will be understood that other types of voltage supplies may be employed. The accelerating anode 22 of the electron gun may be connected to a conventional conducting coating 50 on the interior surfaces of the glass envelope 10 and surrounding the deflection plates 28 and 30. Also the end of the envelope remote from the electron gun may have a conventional fluorescent coating 52 forming a fluorescent screen on the interior thereof.

In the tube above described, the electron gun produces a beam of electrons 24 which is directed toward the screen 52 of the tube through the deflection plates 28 and 30. The velocity of the electrons in the beam during passage through the deflection plates may be of the order of that employed in conventional high sensitivity deflection cathode ray tube for cathode ray oscilloscopes, or may be even somewhat lower so as to provide for greater deflection sensitivity of the tube. Vertical deflection voltages applied between the plates 28 in conjunction with horizontal deflection or sweep voltages applied between the deflection plates 30 cause the beam to be deflected vertically and horizontally, respectively, the boundaries of the vertical deflection of the beam being indicated by the dotted line 24'. It will be understood that a similar deflection is produced in the horizontal direction so that an image is produced. The voltage on the focusing anode 20 of the electron gun is adjusted so that such image is brought to a focus at the focal plane 26. The deflected beam continues forwardly through the electrostatic lens elements 34 and 36. These elements are connected to progressively higher points of positive voltage, such that the electrons in the deflected beams are accelerated and the deflected beam is bent toward the beam axis 32.

An electrostatic accelerating and converging lens, such as that shown in FIG. 1, will, in general, produce spherical aberration of the image provided by the deflected beam of electrons. For one critical adjustment of the voltages applied to the lens elements 34 and 36, a condition can usually be found in which no spherical aberration is present such that an image produced by vertical and horizontal deflection voltages of constant amplitude related to each other so as to cover an area on the screen would have an outline such as shown in FIG. 4. For increased voltages on the elements 34 and 36 produced by varying the position of the contact 48' on the resistor element 42, the spherical aberration tends to produce an image having an outline of the barrel type shown in FIG. 3 and such aberration increases with further decrease of such voltage. For decreased voltages on the elements 34 and 36, the aberration tends to produce an image having an outline of the pincushion type shown in FIG. 2. For a magnetic converging lens, such as that provided by the coil 38, however, the aberration tends to produce an image having an outline of the barrel type shown in FIG. 3. Such aberration becomes progressively greater as the current in the coil 38 is increased to increase the converging effect. By employing both types of lenses, the deflected beams can be made to cross the beam axis 32 at a crossover point 54 to produce a reversed image upon the screen 52 of the cathode ray tube. By adjustment of the positions of the contacts 47 and 48 on the resistor element 42 and the position of the contact 41 on the resistor 40, positions of such controls can be found such that the image on the screen 52 is of approximately the same size that it would be if the magnetic and electrostatic lenses were omitted and such that the two types of spherical aberration discussed above compensate for each other and the image is free from spherical aberration. Such image will be substantially brighter than the image produced in the absence of the lens system, since the electrons in the deflected beam have been accelerated, although the deflection sensitivity of the tube has not been changed. Thus a brighter image of given size may be produced for a given deflection sensitivity.

By simultaneously adjusting the values of the positive voltages upon the element 34 and 36 and at the same time adjusting the current in the coil 38, a magnified image may be produced on the screen 52 which is free from spherical aberration and for a considerable degree of magnification such image is still brighter than the image which would be produced in the absence of the lens system. On the other hand, adjustment of the voltage applied to the elements 34 and 36 and of the current in the coil 38 can be made to produce a smaller image than

that which would be produced in the absence of the lens system and such image can be made free from spherical aberration and substantially brighter than the image produced in the absence of the lens system. It will, of course, be apparent that the movement of the contacts 41, 47 and 48 on their respective resistors may be coordinated so that they can be actuated by a single control. Thus, a brightened image of variable size may be produced by the tube structure of the present invention without varying the deflection energy required and without spherical aberration of the image.

A modification of the lens system is shown in FIG. 5. In such modification, a glass envelope 56 is employed which has a cylindrical portion 57 spaced from but adjacent the screen 52. A conducting coating 58 is applied to the interior of such cylindrical portion to form the equivalent to the cylindrical element 36 of the tube of FIG. 1. Also, the glass envelope 56 may have an inner concentric cylindrical glass element 60 positioned rearwardly of the envelope 56 from the coating 58 and such element 60 may have an interior conducting coating 62 forming the equivalent of the lens element 34 of FIG. 1. The coil 38 forming the magnetic converging lens may surround the envelope 56 (FIG. 5) in the same manner of the similar coil 38 surrounds the envelope 10 of the tube of FIG. 1. Thus, FIG. 5 forms a somewhat simpler structure which is equivalent to the structure of FIG. 1 and it will be apparent that the remainder of the structure of the tube of FIG. 5 may be the same, or similar, to that shown in FIG. 1. While a specific type of electron gun and a specific type of electrostatic accelerating and magnetic converging lens has been shown, it will be understood that other suitable types of electron gun or electrostatic or magnetic converging lens known to those skilled in the art may be employed and that the lens system of the present invention may be employed with cathode ray tubes having magnetic focusing or magnetic deflection, or both.

While preferred embodiments of the invention have been disclosed, it is to be understood that the details thereof may be varied and that the scope of the invention is to be determined by the following claims.

I claim:

1. A cathode ray tube comprising an electron gun for producing a beam of electrons, deflection means for deflecting said beam to provide an image, electron accelerating means for accelerating the electrons in said beam in a direction longitudinally of said beam after said beam has been deflected by said deflection means, said electron accelerating means including an electrostatic converging and accelerating lens surrounding the deflected beam, said lens producing spherical aberration of said image, and a magnetic converging lens also surrounding said deflected beam to correct for said aberration.

2. A cathode ray tube comprising an electron gun for producing a beam of electrons, deflection means for deflecting said beam to provide an image, electron accelerating means for accelerating the electrons in said beam in a direction longitudinally of said beam after said beam has been deflected by said deflection means, said electron accelerating means including an electrostatic converging and accelerating lens surrounding the deflected beam, said lens producing spherical aberration of said image, and a magnetic converging lens also surrounding said deflected beam to correct said aberration, said lenses acting together having sufficient converging action to produce a reversal of said image.

3. A cathode ray tube comprising an electron gun for producing a beam of electrons, deflection means for deflecting said beam to provide an image, electron accelerating means for accelerating the electrons in said beam in a direction longitudinally of said beam after said beam has been deflected by said deflection means, said electron accelerating means including an electrostatic converging and accelerating lens surrounding the deflected beam, said

lens producing pincushion spherical aberration of said image, and a magnetic converging lens also surrounding said deflected beam and producing compensating spherical aberration to correct for the spherical aberration produced by said electrostatic lens, said lenses acting together having sufficient converging action to produce a reversal of said image.

4. A cathode ray tube comprising an electron gun for producing a beam of electrons in said tube directed along a beam axis, a screen in said tube upon which said beam of electrons impinges, deflection means for deflecting said beam out of said axis to produce an image, electron accelerating lens means positioned between said deflection means and said screen for accelerating the electrons in the deflected beam in a direction longitudinally of said beam and bending said deflected beam toward said axis, said electron accelerating lens means including an electrostatic converging and accelerating lens producing spherical aberration of said image, and including a magnetic converging lens producing spherical aberration correcting the spherical aberration produced by said electrostatic lens, said electrostatic and magnetic lenses acting together having sufficient converging action to produce a reversed and magnified image on said screen.

5. A cathode ray tube comprising an electron gun for producing a beam of electrons in said tube directed along a beam axis, a screen in said tube upon which said beam of electrons impinges, deflection means for deflecting said beam out of said axis to produce an image, electron accelerating lens means positioned between said deflection means and said screen for accelerating the electrons in the deflected beam in a direction longitudinally of said beam, said electron accelerating lens means including an electrostatic converging and accelerating lens producing spherical aberration of said image, and including a magnetic converging lens correcting for spherical aberration produced by said electrostatic lens, said electrostatic and magnetic lenses together to cause said electrons to strike said screen at greater velocity than their velocity during deflecting of said beam and having sufficient converging action to produce a reversed image on said screen.

6. A cathode ray tube comprising an electron gun for producing a beam of electrons in said tube directed along a beam axis, a screen in said tube upon which said beam of electrons impinges, deflection means for deflecting said beam out of said axis to produce an image, electron accelerating lens means positioned between said deflection means and said screen for accelerating the electrons in the deflected beam in a direction longitudinally of said beam and bending said deflected beam toward said axis, said electron accelerating lens means including an electrostatic converging and accelerating lens producing pincushion spherical aberration of said image, and including a magnetic converging lens producing spherical aberration correcting for that produced by said electrostatic lens, said electrostatic and magnetic lenses acting together to cause said electrons to strike said screen at greater velocity than the velocity of said electrons during deflection of said beam and having sufficient converging action to produce a reversed and magnified image on said lens.

7. A cathode ray tube comprising an electron gun for producing a beam of electrons in said tube directed along a beam axis, deflection means adjacent said gun for deflecting said beam out of said beam axis to produce an image, focusing means for bringing said image to a focus in a focal plane intermediate the path of said beam in said tube, electron accelerating and converging lens means surrounding the deflected beam on the side of said focal plane opposite said deflection means, said lens means including an electrostatic accelerating and converging lens accelerating the electrons in said deflected beam in a direction longitudinally of said beam and bending said deflected beam toward said axis, said lens producing pincushion type spherical aberration of said image, said lens means also including a magnetic converging lens also

7

bending said deflected beam toward said axis and producing barrel type spherical aberration so as to correct the aberration produced by said electrostatic lens, a screen upon which the electrons of said beam impinge after passing through said lens means, said lens means having sufficient converging action to cause the deflected beam to cross said axis and produce an inverted image on said screen.

8. A cathode ray tube comprising an electron gun for producing a beam of electrons in said tube directed along a beam axis, deflection means adjacent said gun for deflecting said beam out of said beam axis to produce an image, focusing means for bringing said image to a focus in a focal plane intermediate the path of said beam in said tube, electron accelerating and converging lens means surrounding the deflected beam on the side of said focal plane opposite said deflection means, said lens means including an electrostatic electron accelerating and beam converging lens accelerating the electrons in said deflected beam in a direction longitudinally of said beam and bending said deflected beam toward said axis, said lens producing pincushion type spherical aberration of said image, said lens means also including a magnetic converging lens also bending said deflected beam toward said axis and producing barrel type spherical aberration

8

so as to correct for aberration produced by said electrostatic lens, a screen upon which the electrons of said beam impinge after passing through said lens means, said lens means having sufficient converging action to cause the deflected beam to cross said axis and produce an inverted image on said screen, and means for adjusting the converging effect of both of said lenses to vary the size of said image on said screen without producing spherical aberration therein.

References Cited in the file of this patent

UNITED STATES PATENTS

2,289,906	Epstein	July 14, 1942
2,498,354	Bocciarelli	Feb. 21, 1950
2,545,120	Swedlund	Mar. 13, 1951
2,587,074	Sziklai	Feb. 26, 1952
2,689,926	Bond	Sept. 21, 1954
2,696,571	Law	Dec. 7, 1954
2,827,592	Bramley	Mar. 18, 1958
2,892,962	Ross	June 30, 1959
2,944,174	Taylor	July 5, 1960

FOREIGN PATENTS

876,915	France	Nov. 23, 1942
---------	--------	---------------