

May 3, 1960

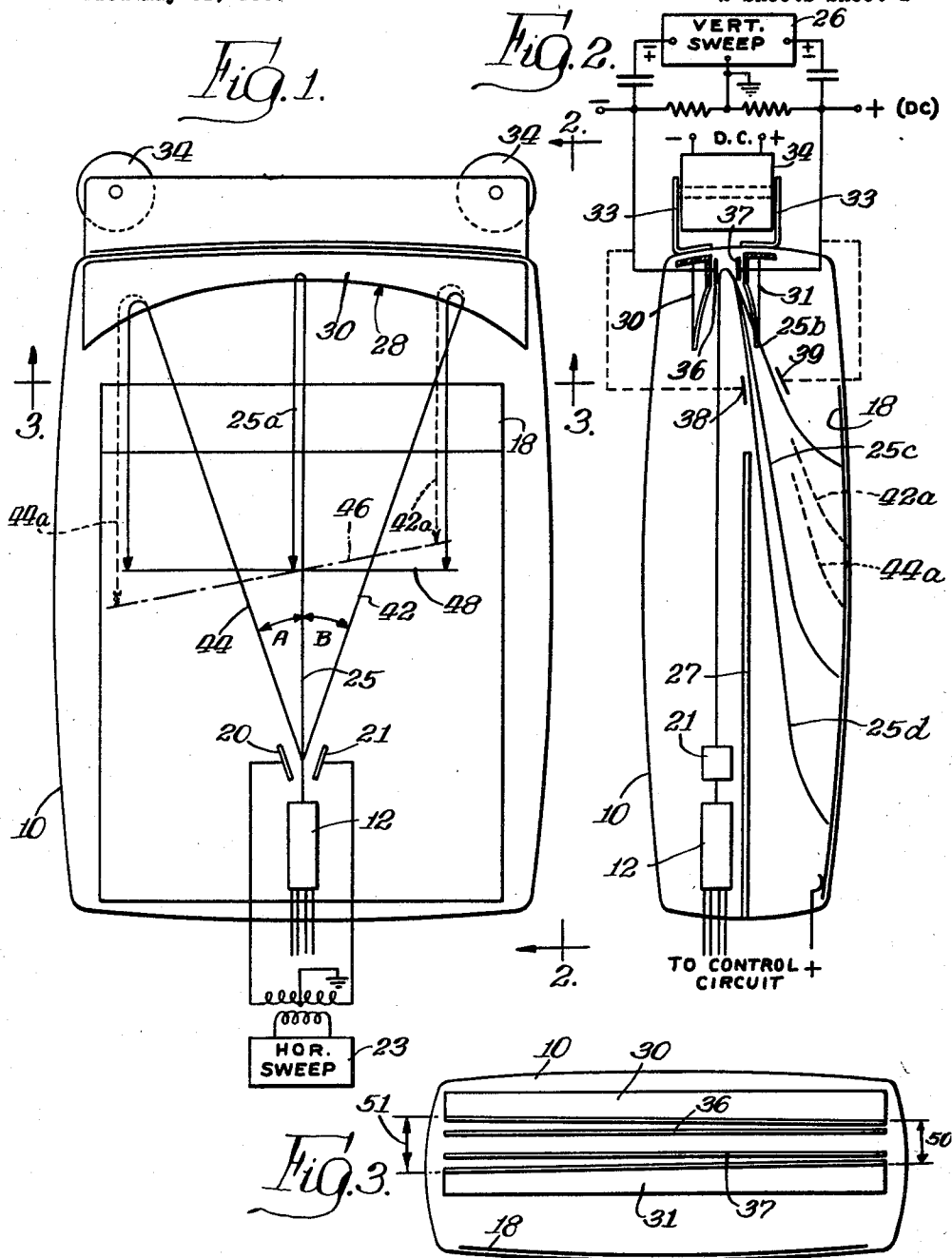
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2,935,643

CATHODE RAY TUBE

Filed May 31, 1957

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4.

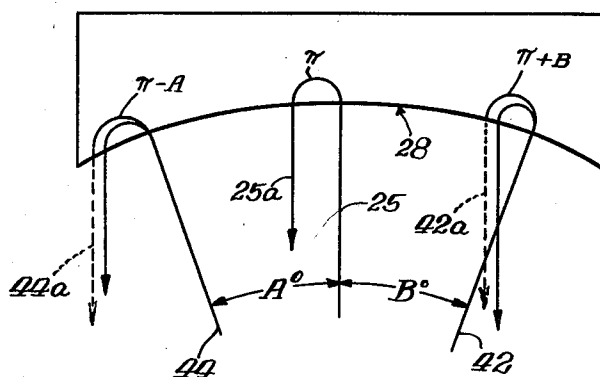


Fig. 5.

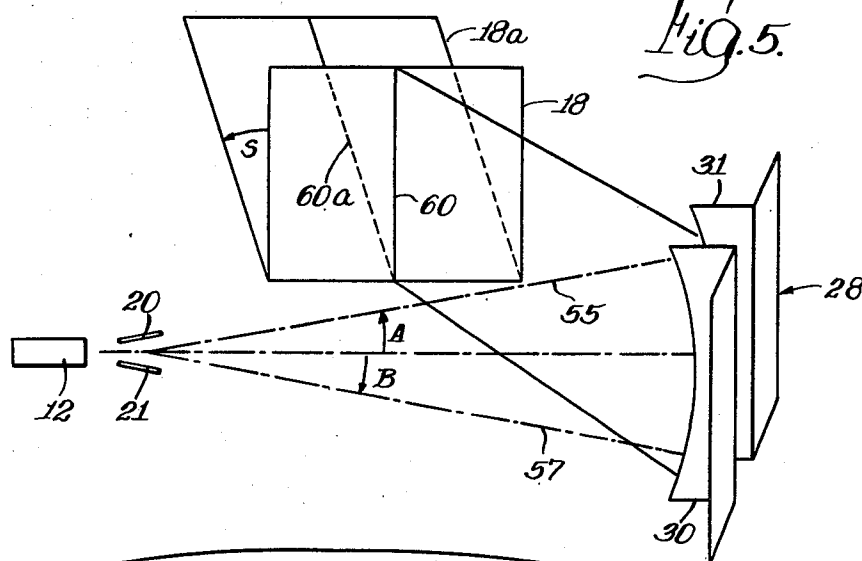
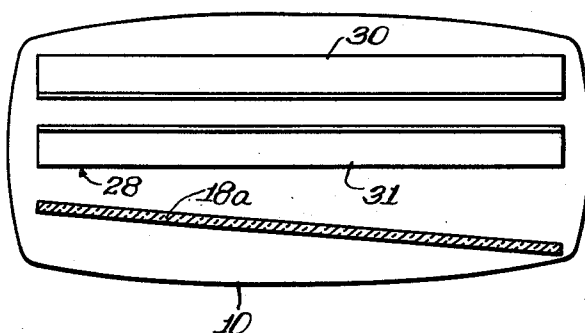


Fig. 6.



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CATHODE RAY TUBE

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Application May 31, 1957, Serial No. 662,638

11 Claims. (Cl. 315—23)

This invention relates to cathode-ray image display devices and more particularly to cathode-ray tubes which are of reduced depth or thickness so that a comparatively flat structure is formed.

Most present day electron image display devices, or cathode ray tubes, are rather long structures with an electron gun spaced a considerable distance from the screen or target. This adds to the bulk of any apparatus in which the device is used. Accordingly, effort has been directed to the problem of devising a more compact cathode ray tube. My copending application, filed April 4, 1956, and bearing Serial No. 576,204 describes and claims a cathode ray tube in which the electron beam is directed into an electron mirror and then folded or redirected to a position for impingement upon a screen, thereby forming a device which is flat and compact. Scanning of the beam in one direction is obtained by deflection parallel to, and beyond, the viewing screen before entry of the beam into an electron optical reflecting device, used to fold the plane of deflected rays by almost 180 degrees. This electron optical device which can make use of electrostatic fields or of mixed electric and magnetic fields, the design of which is part of this invention, is hereafter referred to as an electron mirror. The electron mirror is elongated and supported in a first plane substantially parallel to the screen to accommodate the beam in its various deflected positions prior to further deflection in a second plane which is perpendicular to the first plane.

Such an electron mirror for redirecting the beam may include both magnetic and electrostatic fields for reversing the path of travel of the beam and elevating it or directing it away from the plane of incidence into the mirror. However, details of the mirror construction have decisive influence on beam deflection, particularly deflection occurring before entry into, or during passage through, the mirror. Furthermore, since the beam is not filamentary, or infinitely thin, some defocussing or astigmatism occurs because of the mirror, and it is, of course, desirable to minimize this effect. Obviously, the reduction of such defocussing would preferably be accomplished in a way which does not complicate beam deflection circuits used for the tube.

An object of the present invention is to provide a relatively thin or flat electron image display device wherein defocussing of the electron beam is minimized.

Another object is to provide a cathode ray tube wherein the beam is redirected or reflexed to reduce the dimensions of the tube and the redirecting apparatus is related to the beam deflecting angle to simplify the deflection circuits required.

Still another object is to provide a cathode ray tube of flat construction which produces a scanned pattern of uniform shape and one which is aligned with the axial dimensions of the tube.

A still further object is to provide a novel, magnetic electron mirror which can reflex or "fold" a beam with but minimal astigmatism.

A feature of the invention is the provision of an elec-

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tron image display device in which the beam is deflected through various angles and is then redirected by an electron mirror so that it may impinge a screen. Portions of the mirror and the screen may be skewed with respect to each other so that beam folding and beam deflection angles are related to maintain focus.

Another feature is the provision of a novel magnetic electron mirror wherein the intensity of the mirror magnetic field varies throughout the length thereof so that a uniform focal throw of the beam from the mirror is maintained.

Still another feature of the invention is the provision of an electron mirror which employs combined magnetic and electrostatic fields for electron reflection with a screen thereof disposed in skewed relation with respect to the mirror so that the angle of beam arrival thereon, as it emerges from different portions of the mirror, is constant and defocussing effects in the electron mirror are minimized.

Fig. 1 is a rear elevational view of a cathode ray tube constructed in accordance with the invention;

Fig. 2 is a side view of the tube of Fig. 1;

Fig. 3 is a sectional view along the line 3—3 of Fig. 1;

Fig. 4 is a diagram useful in explaining the invention;

Fig. 5 is a diagram useful in explaining a modified form of the invention; and

Fig. 6 is a view of the modified form corresponding to that of Fig. 3.

The invention provides a cathode ray image display device of short depth or thickness. The device includes a magnetic electron mirror into which a beam is directed from a gun and across which the beam is scanned in a given scanning plane by suitable first deflecting means. The electron mirror includes spaced pole-pieces between which is established a magnetic field for reversing the path of the beam and an electrostatic field for directing the beam outwardly from the plane. A beam target or screen is disposed in spaced relation from the plane so that the beam may be made to impinge the same. This screen and the pole pieces of the mirror are skewed, or supported in angular relation with respect to one another, and the intensity of the magnetic field is related to the angular position of the screen so that beam focus and a desirable image alignment upon the screen are obtained as the beam is scanned through the scanning plane. The described relation may be established by variation in the magnetic field along the electron mirror so that the diameter of the beam orbit (or beam time within the mirror) changes with sweep angle to provide constant transit time in the mirror field. It is further possible to tilt the screen with respect to the electron mirror so that a constant screen impingement angle is maintained and the image is not askew on the screen.

Considering the invention in greater detail, Figs. 1, 2 and 3 which show one form of the invention, will now be described. The image display device or tube includes an evacuated enclosure 10 and an electron gun 12. The enclosure 10 may be formed of glass with convex sides to withstand air pressure. Gun 12 is connected to a suitable beam control circuit (not shown) for a given application of the cathode ray tube. In this form of the invention screen 18 is a coating deposited upon the face of the enclosure 10 and connected to a positive potential source to form a beam target for the tube. It should be noted that the enclosure 10 can be formed of transparent material so that screen 18 may be viewed from either side of the device if this is desirable.

At the exit of the gun 12, the electron beam is deflected by plates 20 and 21 which are connected to a source 23 of horizontal sweep signals so that the beam may be deflected through angles A and B in a scanning plane, these

angles generally being equal and on opposite sides of a central beam path 25.

The deflected beam is directed past and parallel to shield 27 into an electron mirror 28 which is disposed beyond the upper edge of screen 18 (Figs. 1 and 2), so that as the beam emerges from mirror 28 it may be directed into the screen 18. The electron mirror 28 includes a pair of spaced, L-shaped magnetic pole pieces 30 and 31 in the gap between which a magnetic field is established for collimating the beam, or returning it in a path 25a parallel to its path of entry as shown in Fig. 1. An external exciter magnet 33 is shown in flux-coupling relation with pole-pieces 30, 31. The exciter comprises coils 34 which are energized by a direct current to provide the magnetic field. The same function may also be performed by suitable permanent magnets.

The electron mirror 28 further includes a pair of non-magnetic plates 36 and 37 disposed in spaced relation between pole pieces 30 and 31 so that they are straddling the scanning plane of the beam. In the gap between these plates there is formed an electrostatic field by energizing the plates with a voltage of the polarity shown.

Assuming that the beam is travelling the central path 25 it may be seen that upon entering mirror 28 the magnetic field will turn the beam through a given arc and return it along path 25a as shown in Fig. 1. The beam will further be elevated, or directed away from the plane of incidence by virtue of an electrostatic field set up between the electrostatic plates 36, 37. These are polarized as shown in Fig. 2, with the positive plate on the screen side of the beam scanning plane. Thus, the beam may be elevated by controlled amounts under the influence of suitable scanning voltages from a vertical sweep generator 26. (Plates 38, 39 may also be coupled to circuit 26 for scanning purposes). In Fig. 2 various degrees of vertical deflection are designated paths 25b, 25c and 25d. It is contemplated that the beam hit the screen center after electrostatic elevation by approximately 25°.

In Fig. 1 the edges of mirror 28 (members 30, 31, 36, 37) which face the gun 12, are parabolic in shape with the focal point of the parabola at the center of deflection of plates 20, 21. Under this condition, it can be shown that the beam, after being predeflected through angles A and B, will be collimated or returned in paths parallel to path 25. This parabolic mirror shape and the resulting beam collimation also cures the tendency for "keystone" shaping of a pattern on screen 18 where the pattern is smaller near the mirror (top of the screen) than it is at more remote positions on the screen when the beam is swept in both directions on the screen.

It may be seen in Figs. 1 and 4 that when the beam is deflected through angle B and travels path 42 the angle through which the beam turns in mirror 28 will be pi plus B. Furthermore, when the beam is deflected through angle A to travel path 44 the turning angle in mirror 28 will be pi minus A. Accordingly, the transit time in the mirror when the beam is travelling path 42 is considerably longer than it is when the beam is travelling path 44. Therefore, since the beam is within the mirror 28 for a longer time it will emerge with an increased elevation angle (with respect to the scanning plane), namely, along path 42a. Similarly, at path 44 the beam is within the mirror for a shorter time, and the elevation angle will be smaller than at center and the beam will be depressed as shown along path 44a. Under these conditions deflection of the beam through angles A and B in its scanning plane will produce a display trace 46 which is skewed with respect to the central axis of the tube. Furthermore, it has been found that this trace does not stay in focus on the plane of the screen 18, the discussion of which is given in connection with Figs. 5 and 6.

In order to correct this deflection defocussing and produce a sharp horizontal trace 48, the transit time within mirror 28 is suitably controlled in relation to the point of incidence on the electron mirror. The transit time de-

pends upon the radius of curvature within the mirror and the radius is governed by the formula:

$$r = \frac{3.37\sqrt{E}}{B}$$

where B is the magnetic field strength and E is the electron beam potential. The magnetic field strength may thus be varied along the length of mirror 28 to provide the desired transit time therein. As most clearly shown in Fig. 3, this may be done by making the gap width between the magnetic pole pieces 30 and 31 greater at the portion of the mirror in which the beam is turned through less than 180° than it is at the portion of a mirror in which the beam is turned through an angle of greater than 180°, i.e. gap 51 is greater than gap 50. The electric field, on the other hand, is not modified, as is the magnetic field, but it is kept uniform all along the extent of the electron mirror. This is accomplished by keeping the spacing between the non-magnetic pole pieces 36—37 constant. The electric field set up between these electrodes by voltage (D.-C.) is then constant throughout. As a result, by decreasing the path curvature at one end of the mirror and increasing it at the other end of the mirror, the electron transit time is made constant and since the electrostatic field is also constant throughout, the beam leaves the mirror with a uniform angle of elevation. Moreover, since the length of the beam path in the mirror is now constant, the focal throw from the mirror outward is also constant.

In a practical construction of the invention the magnetic pole pieces 30 and 31 may be 12" in length and formed of Mu metal. The scanning angles A and B may be 20° each. The air gap 50 may be 0.67" and the gap 51 may be 0.83". A formula for the ampere-turns providing the magnetic field for the pole pieces is as follows: $ni = 4.2 \tan M \sqrt{E}$ where M is the angle of elevation from the plane of incidence and E is the beam potential. The necessary gap widths between the poles in order to avoid grazing of the mirror by the beam, may be determined from the following formula:

$$g = \frac{\pi}{2} R \tan M$$

where R is the radius of the trajectory within the mirror and M is the angle of elevation from the beam of incidence.

As previously mentioned the electron mirror may cause defocussing of the beam such that a properly focussed trace does not lie in a plane parallel to the mirror, e.g., the scanning plane defined in Fig. 1 by paths 25, 42 and 44. I have found that the trace may originally focus along a line which deviates from the scanning plane by as much as 27°. However, if the above transit time correction is applied this deviation may be reduced to 9° or less.

This condition is illustrated in Fig. 5 wherein the beam is deflected in the scanning plane through angle A to travel path 55 and through angle B to travel path 57. After emerging from the mirror 28, only pole pieces 30, 31 thereof being shown for simplicity, the trace 60 on screen 18 is found to be partly defocussed when the screen is positioned parallel to the plane of mirror 30. Proper focus may be restored, however, by tilting the screen with respect to the scanning plane through an angle S until trace 60a is properly maintained in focus on the tilted screen 18a.

Fig. 6 is a view of the tube corresponding that of Fig. 3 and shows the screen 18a tilted with respect to the scanning plane which coincides with the plane of symmetry of the mirror 28.

This invention provides therefore, an electron image display device which may be constructed as a comparatively flat unit. Necessary focussing of the beam is maintained throughout the first scanning operation (as the beam is deflected through angles A and B) and astigmatism, which could otherwise be caused by mirror

28, is thus prevented. The method of correcting such defocussing involves comparatively simple structural arrangements within the tube. This permits the use of scanning signals of conventional wave forms which may be produced by simple sweep circuits at 23 and 26. It should also be pointed out that the cathode ray tube as described will permit an unobstructed view of the screen 18 from either one or both sides thereof, which feature may provide utility in certain applications. Furthermore, the tube will be free from ion-burn since an electron mirror of the electromagnetic type is used which does not reflect ions originating in the electron beam.

I claim:

1. An electron beam image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane and directing the same into various portions of said mirror, said mirror including spaced portions and means to establish therebetween a magnetic field for reversing the travel of said beam and an electrostatic field for directing said beam outwardly from said plane, a beam target spaced from said plane so that said beam may be directed onto the same, said beam target being angularly disposed with respect to said given plane and such angular disposition being related to the intensity of said magnetic field along said mirror so that focussing of said beam upon said target is obtained throughout a given cycle of beam deflection in said plane.

2. An electron image display device including in combination, an elongated electron beam mirror for reversing the direction of travel of a beam, means supplying an electron beam and directing the same into said mirror, deflecting means for scanning said beam in a given plane, said mirror including pole portions spaced on opposite sides of said given plane and having substantially parabolic shape along edges thereof facing said deflecting means, said pole portions being adapted to provide a magnetic field across said plane for collimating said beam and an electrostatic field across said plane for directing said beam away from said plane, a beam target spaced outwardly from said plane and positioned so that said beam is directed onto the same, the plane of said beam target and at least one of said pole portions of said mirror being disposed in non-parallel relation with respect to one another, and the intensity of said magnetic field along said mirror being related to the angular position of said beam target so that focus of said beam upon said target is maintained throughout a given cycle of beam deflection in said plane.

3. An electron beam image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane and directing the same into various portions of said mirror, said mirror including spaced portions and means to establish therebetween a time fixed magnetic field for reversing said beam and a time fixed electrostatic field for directing said beam away from said given plane, a beam target spaced outwardly from said given plane and terminating on the side of said mirror toward said means supplying an electron beam so that said beam may be directed onto the same, means providing a time variable field operative upon said beam after the same enters said mirror for deflecting said beam in a further plane substantially perpendicular to said given plane, the plane of said beam target and at least one of said spaced portions of said mirror being skewed with respect to one another, with the intensity of said time fixed magnetic field and said time variable electrostatic field along said mirror being related to the angular position of said beam target so that focussing of said beam upon said target is ob-

tained throughout a given cycle of beam deflection in said given plane.

4. An electron image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of electrode members spaced on opposite sides of said given plane, said electrode members being adapted to provide a magnetic field across said plane for redirecting said beam and an electrostatic field across said plane for directing said beam outwardly from said plane, a beam target spaced outwardly from said plane and positioned so that the beam is directed onto the same, at least one of said electrode members being disposed in non-parallel relation with respect to said given plane so that the intensity of at least one of the fields in said mirror is varied therealong to provide uniform redirecting of the beam by said mirror with respect to said target.

5. An electron image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of electrode members spaced on opposite sides of said given plane, said electrode members being adapted to provide a magnetic field across said plane for redirecting said beam and an electrostatic field across said plane for directing said beam outwardly from said plane, a beam target spaced outwardly from said plane and positioned so that the beam may be directed onto the same, a pair of said electrode members disposed in variable gap relation with respect to said given plane with the intensity of said magnetic field across said mirror being varied therealong in correspondence with the angle of deflection of said beam in said given plane so that the beam transit time in said mirror is constant whereby focus of said beam on said target is substantially maintained in the deflected positions thereof.

6. An electron image display device including in combination, an elongated electron beam mirror for redirecting the beam, means for supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of pairs of field producing members disposed on opposite sides of said plane, a first pair of said members having a substantially parabolic edge facing said deflecting means and being adapted to provide a magnetic field of substantially parabolic shape across said plane for reversing and collimating said beam by turning the same through greater than 180° in one scanned position and less than 180° in another scanned position, a second pair of said members being adapted to provide an electrostatic field across said plane for directing said beam away from said plane, a beam target spaced outwardly from said plane and positioned so that the beam may be directed onto the same, said first pair of members being spaced more closely wherein said beam is turned through greater than 180° than the same are spaced wherein said beam is turned through less than 180° so that the magnetic field intensity is varied along said mirror in accordance with the angle through which the beam is turned and substantially constant transit time of said beam in different positions within said mirror is maintained.

7. An electron image display device including in combination, an elongated electron beam mirror for redirecting a beam, means for supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of field producing members disposed on opposite sides of said plane, a first pair of said members having a substantially parabolic edge facing said deflecting means and being adapted to provide a magnetic

field of substantially parabolic shape across said plane for turning said beam through an arc and returning the same along parallel paths with the arc subtended being variable and dependent upon the scanned position of said beam produced by said deflecting means, a second pair of said members being adapted to provide an electrostatic field across said plane for directing said beam away from said plane, a beam target spaced outwardly from said plane and positioned so that the beam may be directed onto the same, said first pair of members being spaced more closely at positions where said arc is angularly greater than where the same is less so that the magnetic field intensity is varied in accordance with the angle through which the beam is turned, whereby transit time of said beam in said mirror is substantially constant and focussing of said beam upon said target is maintained during beam deflection in said plane.

8. An electron image display device including in combination, an elongated electron beam mirror for reversing the direction of travel of a beam, means supplying an electron beam and directing the same into said mirror, deflecting means for scanning said beam in a given plane, said mirror including members spaced on opposite sides of said given plane, said members being adapted to provide a magnetic field across said plane for reversing the travel of said beam and an electrostatic field across said plane for directing said beam away from said plane, a beam target spaced outwardly from said plane and positioned so that said beam is directed onto the same, said beam target being disposed in non-parallel relation with respect to said given plane, with the spacing between said mirror and said beam target for a given cycle of beam deflection in said plane varying in accord with such deflection to maintain focus of said beam on said beam target.

9. An electron image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of electrode members spaced on opposite sides of said given plane, said electrode members being adapted to provide a magnetic field across said plane for redirecting said beam and an electrostatic field across said plane for directing said beam outwardly from said plane, a beam target spaced outwardly from said plane and positioned so that the beam is directed onto the same, at least one of said electrode members being disposed in non-parallel relation with respect to said given plane so that the intensity of the magnetic

fields in said mirror is varied therealong to provide uniform redirecting of the beam by said mirror with respect to said target and circuit means providing time variable signals to said electrode members for further control of said beam.

10. An electron image display device including in combination, an elongated electron beam mirror for redirecting a beam, means supplying an electron beam and directing the same toward said mirror, deflecting means for scanning said beam in a given plane, said mirror including a plurality of electrode members spaced on opposite sides of said given plane, said electrode members being adapted to provide a time fixed magnetic field across said plane for redirecting said beam and an electrostatic field across said plane for directing said beam outwardly from said plane, a beam target spaced outwardly from said plane and positioned so that the beam is directed onto the same, at least one of said electrode members being disposed in non-parallel relation with respect to said given plane so that the intensity of at least one of the fields in said mirror is varied therealong to provide uniform redirecting of the beam by said mirror with respect to said target, and means including further electrode members disposed between said mirror and said beam target to provide a time varying field for further scanning of said beam.

11. An electron image display device including in combination, means supplying an electron beam including means for scanning said beam in a given plane, an elongated electron beam mirror for redirecting said beam, said mirror including electrode members spaced on opposite sides of said given plane and between which said beam is directed, means providing a magnetic field between said electrode members and variable in intensity along the length of said mirror, a beam target spaced outwardly from said given plane and positioned so that the beam may be directed thereon, means for directing said beam outwardly of said given plane to impinge on said beam target, the magnetic field intensity in said mirror being related to the transit time of said beam in said mirror and the length of the path of beam travel between said mirror and said beam target to provide a uniform trace on said beam target throughout the deflected positions of said beam in said given plane.

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