Aug. 8, 1939. J. R. DUNCAN 2,168,978

CATHODE RAY DEFLECTING APPARATUS

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Fig. 1.

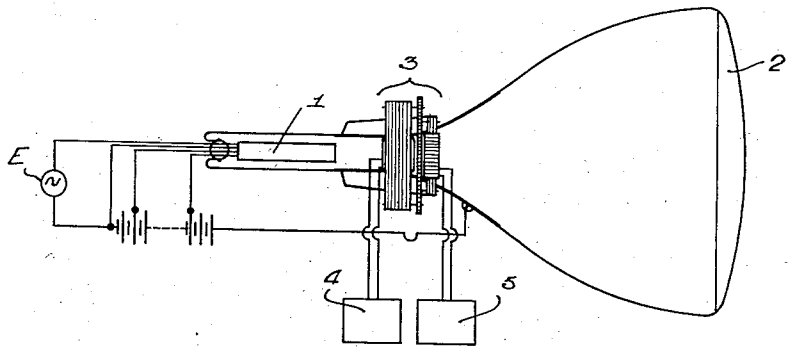


Fig. 3.

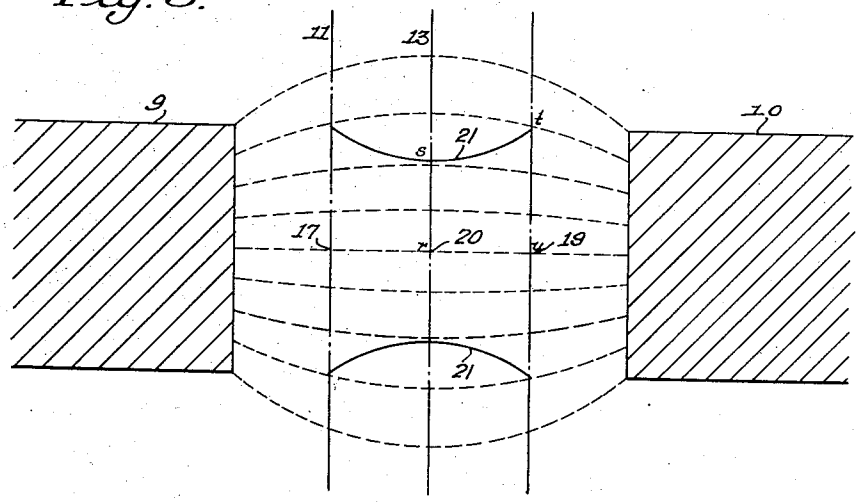


Fig. 4.

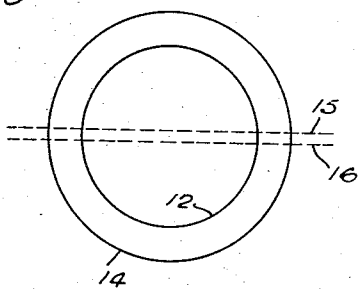
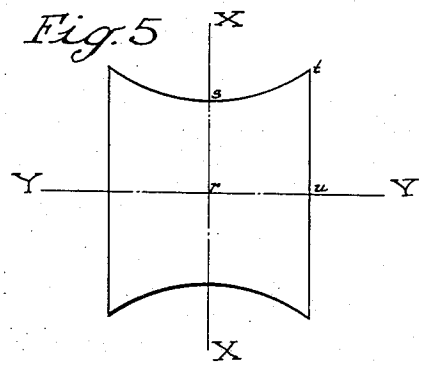


Fig. 5



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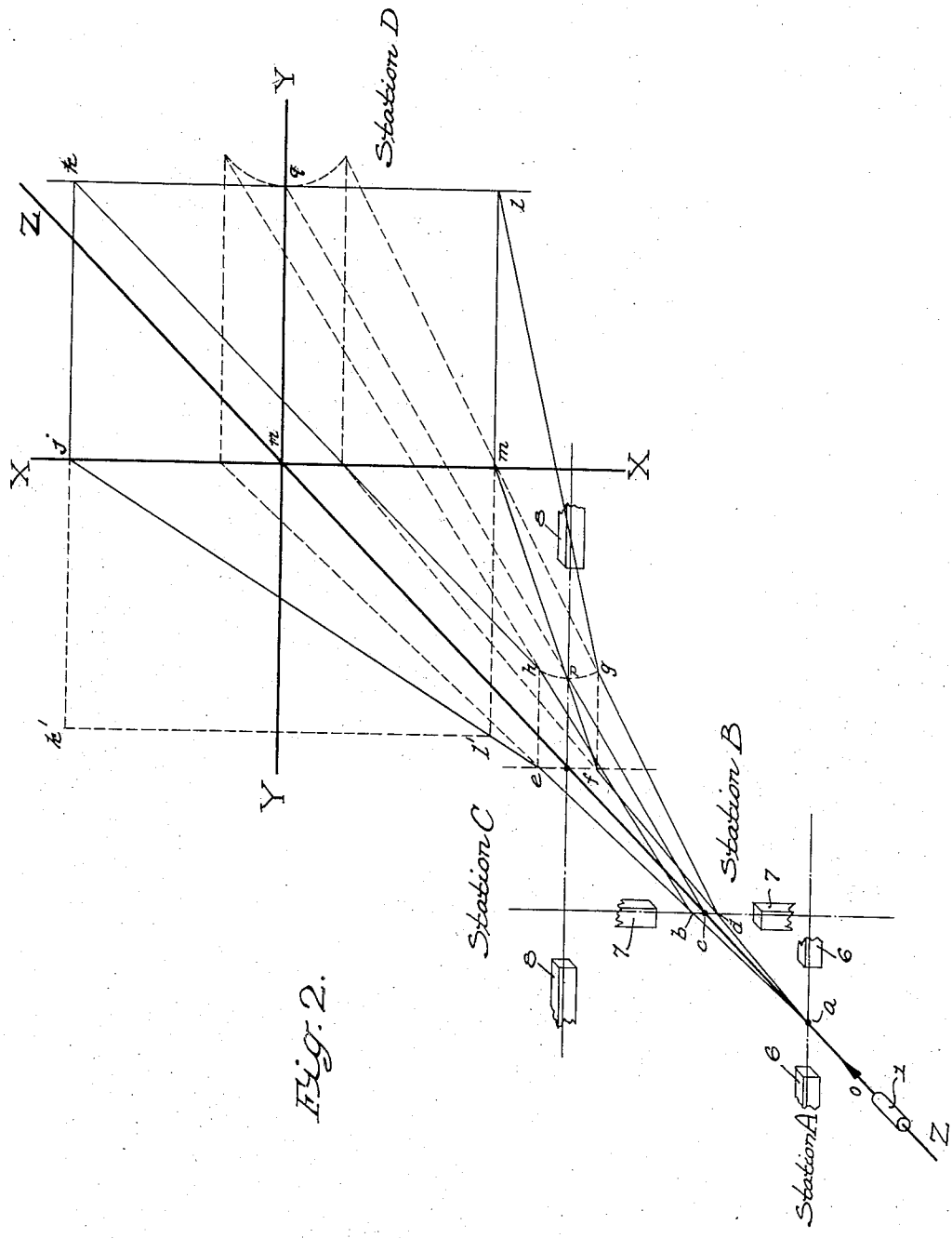


Fig. 2.

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Fig. 6.

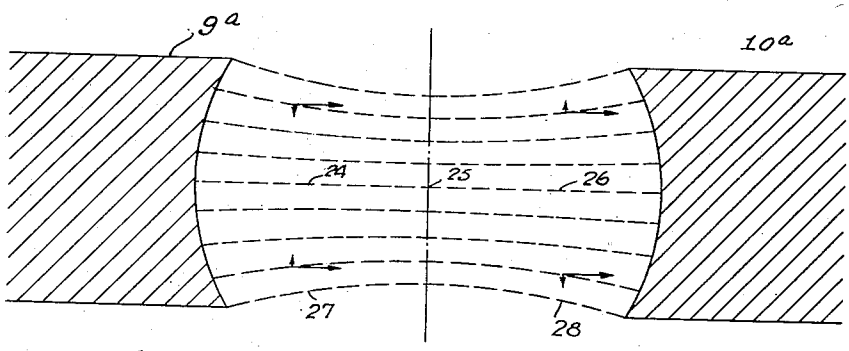


Fig. 7.

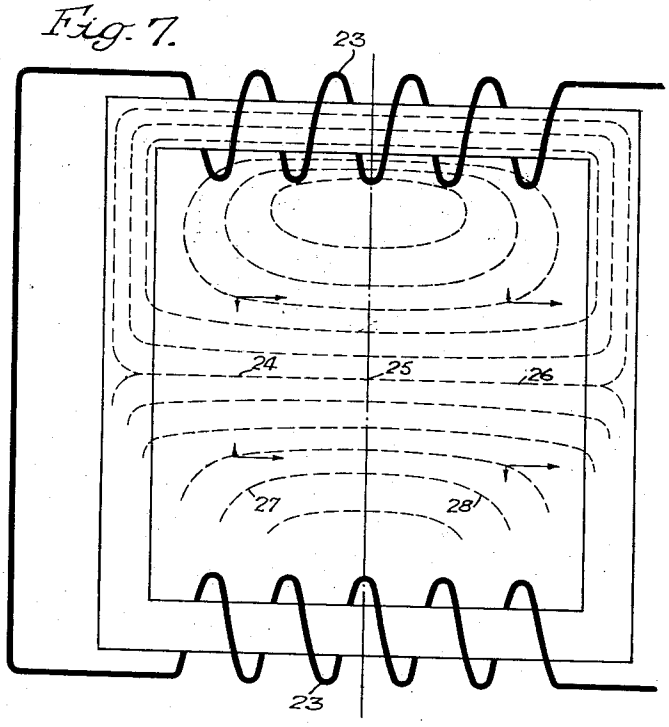
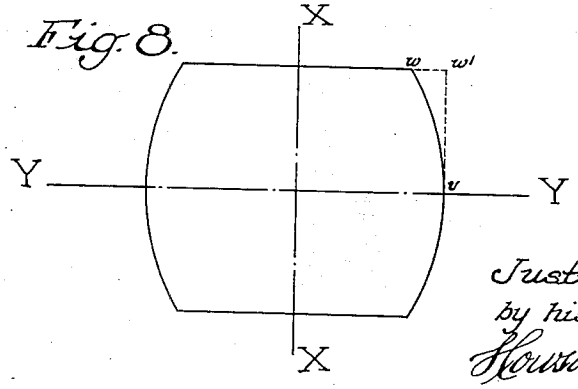


Fig. 8.



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Fig. 9.

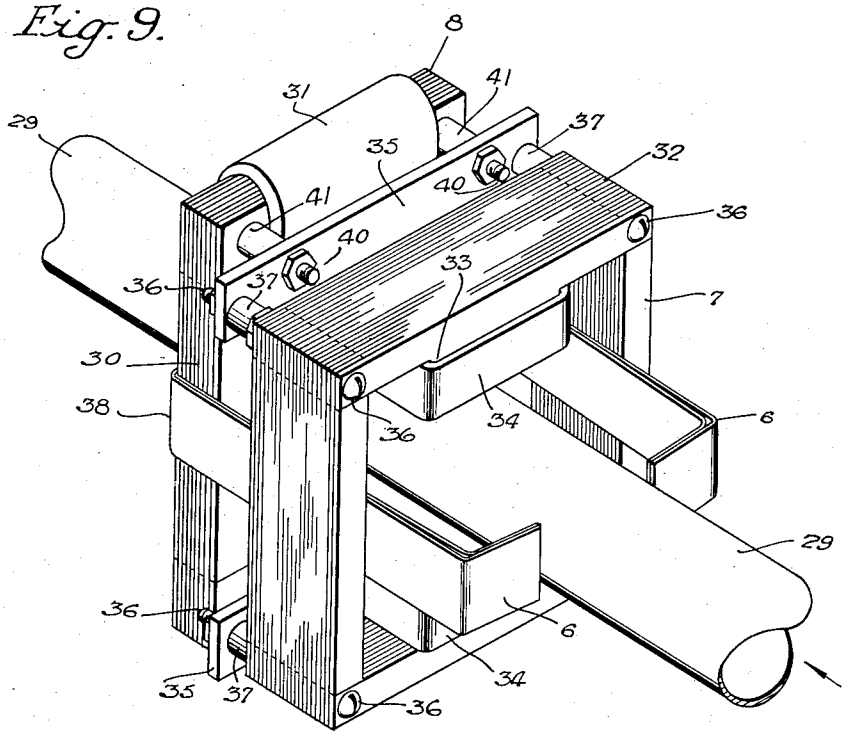
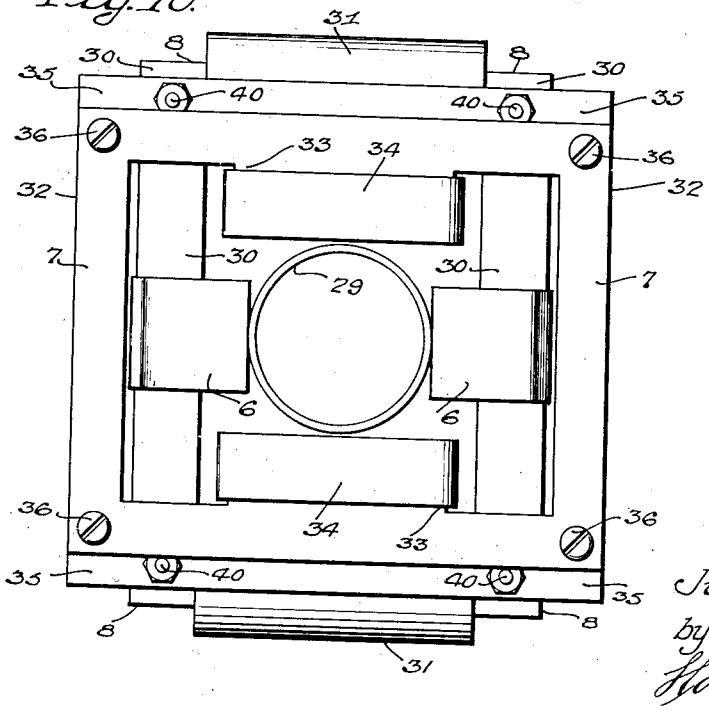


Fig. 10.



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CATHODE RAY DEFLECTING APPARATUS

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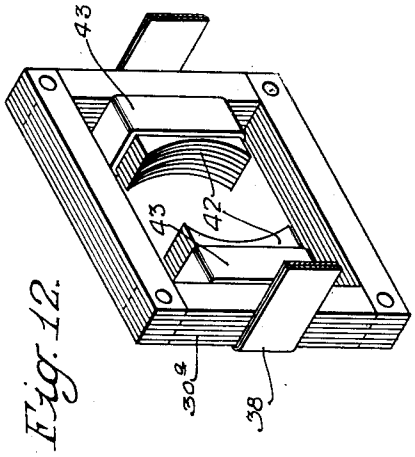


Fig. 12.

Fig. 11.

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UNITED STATES PATENT OFFICE

2,168,978

CATHODE RAY DEFLECTING APPARATUS

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Application February 25, 1936, Serial No. 65,704

9 Claims. (Cl. 250—157)

This invention relates to means for deflecting electron currents in cathode ray tube oscilloscopes and similar devices, wherein it is desired to deflect an electron beam independently in a plurality of directions. The invention provides means by which the precision of deflection may be improved and hence is particularly adapted for use in television systems, wherein the transmitted image is reproduced in a cathode ray tube.

One object of the invention is to provide a structure for deflecting an electron beam by two different fields and to provide a structure such that the deflection may be made proportional to the electric currents or voltages generating the fields and in which there is no distortion in the resulting deflection.

Another object of the invention is to provide a deflecting device by which the several fields may be generated by magnetic structures which are spaced one from another, thus providing a high degree of flexibility and freedom of design of such structures.

Still another object of the invention is to provide means by which distortion due to the movement of the beam in one magnetic field may be corrected by an auxiliary field introduced by the same or another magnetic system.

A further object of the invention is to provide a deflecting device in which the electron beam is deflected by a plurality of fields, the field distribution being non-uniform and so arranged that deflection distortion introduced in one field may be arranged to correct and compensate for distortion introduced in another field, and in which the several fields may be varied without modifying the precision of the resulting deflection pattern.

Other objects of the invention will be apparent from the following description and the accompanying drawings, in which

Fig. 1 is a schematic illustration showing a top or plan view of a cathode ray tube employing an embodiment of the invention;

Fig. 2 is a geometrical illustration of the electron beam deflection obtained by the use of several magnetic fields in accordance with the invention;

Figs. 3 to 8 are diagrammatic illustrations of different types of field structures and the beam deflections which may be caused thereby, enabling a clear understanding of the principles involved in the invention;

Fig. 9 is a perspective view of a preferred form of a device embodying the invention;

Fig. 10 is a front face view of the device;

Fig. 11 is an exploded view showing the parts of the device; and

Fig. 12 illustrates a modification.

In Fig. 1 there is shown in schematic outline, a cathode ray tube of the type now used in the art to obtain visual pictures of the effects of electrical currents and voltages and which may be used in television systems to reproduce visual images from certain types of electrical signals. A device having a similar deflecting system may be used to form electrical signals from a light image. Such a tube comprises an electron gun indicated at 1, which consists of means for producing a supply of electrons and may comprise a heated cathode of conventional form and several accelerating grids, which in cooperation with the cathode serve to form and direct a stream of electrons moving with relatively high velocity along the axis of the tube, as well known. The intensity of the electron stream may be controlled by means of a source of control energy E, as well understood. For the purposes of the present application, an electron gun may be considered to be a device which forms a thin beam or pencil of moving electrons which is emitted from the gun in one direction. These electrons impinge upon a fluorescent screen 2 at the end of the tube, and in so doing lose some of their energy which is radiated from the screen in the form of light, thus forming on the screen a point of light at the spot at which the electron beam impinges. As is well known, the electron beam may be deflected by electrostatic or electromagnetic fields positioned between the gun and the screen. In accordance with the present invention, In Fig. 1 there is shown schematically a device 3 for forming suitable magnetic fields to deflect the electron beam in two mutually perpendicular directions and by which distortion of the deflection in either direction may be prevented. In this particular instance, the fields may be generated by means of electromagnets and the sources of electric current for forming the several fields are indicated at 4 and 5.

In the use of such a device for television purposes, the electron beam is repeatedly and rapidly deflected across the screen in one direction while being, at the same time, periodically deflected at a considerably slower rate in a second direction perpendicular to the first. In this way, the beam traces a series of lines which together form a generally rectangular area made up of fine lines on the receiving screen 2. By varying the intensity of the beam as it delineates these lines, the television picture is produced. A desirable

condition is that the beam deflection be directly proportional to the eletcrical deflecting signal, and that the total deflection in one direction be independent of the total deflection in the other direction. Further, in general television usage, the area ruled on the screen should be a rectangle whose sides are straight.

In the following description, the deflecting system provided by the invention will be described in terms of its use in a television system which presents the most exacting requirements. It will be understood, of course, that the device is likewise suitable to any other usage which may be required of a cathode ray oscillograph. The deflecting device may be used to deflect any high velocity electron beam, whether it is used for transmitting or receiving in television or for any other purpose.

In devices of the prior art it has been customary, when utilizing electromagnetic deflection, to form the two fields by magnetic structures in the same plane. This was done in order that the electron beam might be deflected either horizontally or vertically about the same point. In the use of such a structure it is necessary that each of the magnetic fields be substantially uniform over the area occupied by the electron beam, if distortion is to be eliminated. Certain disadvantages are inherent in such a system. For example, in order to make the two fields uniform it is necessary that large pole pieces be used, but these pole pieces tend to overlap at their corners, thus forming low reluctance short circuiting paths with respect to each other, which seriously decrease the efficiency of the deflecting device. This is particularly disadvantageous in television use, since in order to obtain the high deflection frequency desired without incurring large voltages or currents in the electromagnetic coils, the maximum deflection efficiency should be obtained. Further, when the two field structures are formed in the same plane, the fields cannot be maintained uniform over the beam area unless expensive precautions are taken. Moreover, small deviations from the ideal form, such as might be encountered in any practical form of the device suitable for manufacture by production methods, would introduce serious distortion. Likewise the manufacture of such a structure is rendered expensive by the shape and construction necessary. I have found that these defects may be overcome and that advantages may be obtained by separating the several magnetic fields and by causing the beam to be deflected along a line in one field and within an area in another field, and that by proper design of the several fields, which design admits of a high degree of flexibility, linear deflection may be obtained without the necessity of providing several coplanar parallel or uniform magnetic fields.

In Fig. 2, there is shown the resultant deflection obtained when the several magnetic fields are established in different planes. In the three dimensional figure having coordinates X, Y, and Z, the electron gun 1 emits an electron beam, which in the absence of deflecting fields, would travel along the Z axis as indicated by the arrow. The beam may be deflected in the X direction by a magnetic field established between the pole faces of an electromagnet 6, the direction of this field being along the Y coordinate. For the sake of simplicity, the deflection may be assumed to take place about the point *a*. It will be understood, of course, that the actual deflection is not abrupt, as indicated, but is in the form of a gradual deflection extending for the duration of the field in the Z direction. The electron beam may be deflected along the Y axis by the magnetic field between poles of the field structure 7, which sets up a magnetic field directed along the X axis and spaced in the Z direction from the field structure 6. It will be noted that the intersection of the beam and the magnetic field of structure 7 will take place somewhere along the line *b, c, d*, depending upon the amount of deflection at the point *a*. Somewhat further along the Z axis the beam may be deflected by the magnetic field set up between the pole pieces of field structure 8, which deflects the beam along the X axis by virtue of the component of this field in the Y axis and which also serves to deflect the beam to a limited extent along the Y axis due to the component of the field in the X axis, as will be pointed out in more detail hereinafter. It will be noted, first, that the trace of the intersection of the beam with the field due to the magnetic structure 8 will take place, dependent upon previous deflection, somewhere in an area *e, f, g, h*, and, second, that the amount and direction of deflection will depend upon the position of the beam with respect to this area. The area *j, k, l, m*, represents the trace of the beam on a plane perpendicular to the Z axis, which might, for example, be the figure which the beam would outline on a fluorescent screen placed at the point *n* of the Z axis. The figure may, of course, be outlined on a plane or curved surface. For simplicity a plane surface is assumed. In practice the screen 2 would in general be formed on a curved surface having a center of curvature somewhere on the Z axis between the fields of 6 and 8. Under these conditions the lines *jk, kl, lm* would be considered straight when they corresponded to the intersection of the curved surface with planes parallel to the Z axis.

The following detailed explanation is given to enable a clear understanding of the operation of the system of Fig. 2 and the manner in which this system achieves the objects of the invention. When an electron beam composed of electrons having a high velocity in one direction, which we may call the Z direction, passes through a magnetic field having components in the X and Y directions, and of such magnitude that the angle of resulting deflection is small, the component of velocity perpendicular to the direction of the field and to the Z direction, acquired by the electron beam due to its motion through the magnetic field, will be independent of the velocity with which it entered the field and dependent only upon the total amount of flux traversed by the beam. More specifically under these conditions the acquired velocity will be proportional to the integral of the component of flux density perpendicular to the Z axis along the beam path integrated over the width of the field. The total acquired velocity of the electron beam will be substantially independent of the field distribution along the Z axis. Furthermore, the angle of deflection will be substantially proportional to the ratio of the velocity, in the direction perpendicular to the Z axis and the direction of the field, to the velocity along the Z axis.

Consider now an electromagnet having flat pole pieces, as shown in Fig. 3, the pole pieces being indicated at 9 and 10. Due to the high reluctance of the air gap between the pole pieces,

the field will fringe and tend to spread out, as illustrated. Thus it may be considered that a certain number of tubes of flux emanate from one pole face and converge upon the other pole face, and that on a cross-section of the field in a plane perpendicular to the axis of the structure along the line 11, a certain number of tubes of flux will be enclosed by a circle, such as shown at 12 in Fig. 4. Similarly, on another cross-section of the field in a similar plane taken midway between the pole faces along line 13, the same number of tubes of flux will be enclosed by a larger circle, such as shown at 14 in Fig. 4. If an electron beam were to pass through this field at either of these points in a direction perpendicular to the plane of the paper, the amount of flux traversed by the beam may be approximately represented by the area bounded by the straight lines 15 and 16 and either the circle 12 or the circle 14 of Fig. 4. Remembering that the circles 12 and 14 each enclose the same total amount of flux, it will be seen that the portion of the flux traversed by the electron beam in passing through the smaller circle represents a larger fraction of the total flux than the portion traversed by the electron beam in passing through the larger circle. Since, as above stated, the amount of deflection of the electron beam is dependent upon the total amount of flux traversed in any instance, it will be apparent that the amount of bending, or the amplitude of deflection, of a beam traversing the field at the point 17 or 19 will be greater than that which would be occasioned by the transversal of the beam at the point 20. This difference in the amount of deflection is indicated in Fig. 3 by the curved lines 21, and will be termed "amplitude distortion".

In Fig. 5, there is shown the resulting deflection pattern which would be obtained if an electron beam were deflected horizontally or in the Y direction along the principal axis of Fig. 3 by a uniform field in advance of the field of Fig. 3 and thereafter vertically or in the X direction by the field of Fig. 3. It will be noted that while the horizontal deflection is uniform, the vertical deflection is greater at the sides than at the center, and thus will have amplitude distortion.

For the purpose of this specification and claims, "amplitude distortion deflection" is defined as that component of deflection, in the same direction as the principal deflection direction, by which the deflection of a beam, which traverses the field causing the deflection other than centrally of the field, differs from the deflection of a beam which traverses the said field at the center point. The principal deflection direction is taken as the direction perpendicular to the center line of the field and is, of course, the direction in which the beam would be deflected by a uniform or undistorted field. Thus in Figs. 3 and 5 the amplitude distortion deflection introduced when the beam traverses the field at 19 is the difference between the deflection *t*—*u* and the deflection *r*—*s*.

Referring now to Figs. 6 and 7, there are shown alternative structures by means of which the amplitude distortion may be modified or eliminated. It will be noted that in Fig. 6 the faces of the pole pieces 9*a* and 10*a* have been curved while in Fig. 7 similar results are obtained by adding to the field caused by a rectangular yoke 22, the leakage field from the windings 23. By varying the curvature of the pole pieces in Fig. 6 or by varying the amount of leakage field in Fig. 7, the flux may be caused to take a more uniform direction parallel to the axis of the field. Thus considering the previous illustrations, the cross-sectional circles, enclosing the same total amount of flux, may have the same diameter or the diameters may be made to increase or decrease with respect to cross-sections differently spaced with respect to the pole faces. Thus, the curvature of the field will affect the amount of amplitude distortion and by proper design, the amplitude distortion introduced by causing the beam to traverse the principal axis of the field at different points may be eliminated or caused to vary in some desired manner. In this particular instance, it may be desirable to have no amplitude distortion. In other words, the amount of deflection of the electron beam in the vertical or X direction may be made substantially uniform, regardless of whether the electron beam enters the field at any of the points 24, 25 or 26. Along a cross-sectional median plane equidistant from the pole faces, there will be no component of flux perpendicular to the axis of the field and, consequently, no deflection in the direction of the field. If, however, the beam were to enter the field at either of the points 27 and 28, or at any other such point, there would then be a certain amount of deflection in the direction of the field, due to the perpendicular component of the flux, with respect to the axis of the field, caused by the field curvature.

Assuming a system in which the beam has previously been deflected without distortion in the Y direction and preferably to a limited extent in the X direction and in which this field produces deflection principally in the X direction, this field curvature will cause the electron beam deflection in the horizontal or Y direction to be distorted as indicated in the barrel shaped deflection pattern of Fig. 8, while the deflection in the vertical or X direction may be made uniform, as above described.

It will be seen that the pattern of Fig. 8 involves a second type of distortion, and that whereas the amplitude distortion involves a variation of the amplitude of principal deflection of the electron beam, this second type of distortion comprises a deflection in a direction perpendicular to the direction of principal deflection and tends to distort or vary the direction of principal deflection. This second type of distortion will therefore be termed "direction distortion". The amount of deflection of the electron beam in each direction will be proportional to the field components causing that deflection. For example, in Figs. 6 and 7, the field components at certain points causing deflection in the principal direction are indicated by the longer arrows while the direction distortion components are indicated by the shorter arrows. The directions of deflection will, of course, be perpendicular to the field vectors. It will be observed that the magnitude of the field components in the principal direction is less near the pole faces than midway between them. This change in field intensity is opposite to that previously described as a source of amplitude distortion, and in one sense is a factor which permits the prevention of amplitude distortion, as previously described, by proper design of the field structure. Thus, by proper curvature of the field, which may be obtained by shaping the pole pieces as in Fig. 6 or by modifying the leakage field as in Fig. 7, for example, by varying the length and width of the rectangular yoke, the amplitude of

the principal deflection of an electron beam may be made independent of the position at which the beam intersects the field axis. That is, by simple design, amplitude distortion may be modified or avoided in any one of several ways but in so doing, certain direction distortion is incurred. The direction distortion, however, may then be counterbalanced by amplitude distortion introduced in a second field perpendicular to the first field, as will be more clearly understood later.

For the purpose of this specification and claims, "direction distortion deflection" is defined as that component of deflection in a direction perpendicular to the principal deflection direction which a beam acquires in passing through a modified field. Thus, in Fig. 8, a beam is deflected by a field of the type shown in Fig. 6 or 7 about the axis YY and at one point has a principal deflection *v w'*. Due to the curvature of the field, however, direction distortion deflection *w w'* is introduced so that the resultant deflection is *v w*.

Along the field axis, the field components causing direction distortion balance out, and hence there would be no direction distortion if the beam passed through the field along the plane of the field and the Z axis. However, if the beam enters the field on the axis it will be deflected in transit and, consequently, will not remain in the plane including the field axis. Therefore, some direction distortion will be incurred. Thus, in this instance one may not consider the bending of the beam as occurring at a point but the gradual bending of the beam and its subsequent displacement with respect to the field must be considered. Direction distortion in this particular case may be reduced to zero by causing the field to be zero when the beam is so positioned, and this is done in the practice of the invention as described hereinafter. If the beam does not pass through the field axis but intersects the field at some point such as **27** or **28** (Fig. 6 or 7), then there will be some direction distortion which will increase as the point of intersection is moved further from the median plane or from the field axis or both. The amount of principal deflection at point **28**, for example, may be somewhat less than that which would be caused by the beam passing through a point on the field axis, but if such is the case, by designing to avoid amplitude distortion as above mentioned, this variation becomes proportional to the distance from the point of beam intersection to the principal axis and independent of the distance from the median plane. Thus, this variation will not cause distortion and will not affect the ratio of resulting deflection to the magnitude of the signal causing the deflection.

Referring again to Fig. 2, the field of poles **6** will cause deflection at a point which may be designated station A; the plane of deflection caused by the field of poles **7** may be designated station B; and the plane of deflection caused by the field of poles **9** may be designated station C. Assume for the moment that the field at station A is substantially uniform throughout the small area occupied by the beam, which might be obtained, for example, by a simple field structure having reasonably large pole faces; that the field at station B is that obtained by a field structure having the characteristics shown in Fig. 3, in which there is some amplitude distortion, depending upon the deflection of the beam at station A; and that the field at station C is that obtained by using a field structure such as shown in Fig. 6 or Fig. 7, in which there may be some direction distortion but from which amplitude distortion has been eliminated by the method described above. The paths taken by the electron beam under different field conditions will now be considered.

If none of the fields are energized, that is if there are no deflecting fields whatsoever, the beam would go directly along the Z axis from the point *o* to the point *n* at the receiving screen station D. In other words, the beam would not be deflected at stations A, B and C.

A second condition might be that under which there is no deflection in the X direction, but there is deflection in the Y direction. In this case, there would be no field at stations A and C, but there would be a field at station B. It will be seen that the beam will go from *o* to *c* without being deflected. At *c* the beam is bent in the Y Z plane, going to point *p* at station C, and then to *q* at station D. Since there is no field at station C, the beam will not be bent at the point *p*.

A third condition may exist when the beam is deflected along the X axis but not along the Y axis. In this case, there would be no field at station B, but a certain field at station C, and a proportional field at station A. In this case, the beam is deflected at the point *a*, arriving at point *b* at station B. There is no field at station B, consequently, the beam goes without deflection to point *e* at station C. At point *e* the beam is subjected to further deflection in the X direction, that is the principal deflection due to the field at station C. However, as shown by the flux diagram of Fig. 6 or 7, there will be no direction distortion of the beam since it cuts this field along a plane midway between the pole faces. Thus the beam will arrive at point *j* of station D.

Consider now the fourth case in which the beam is deflected in both the X and Y directions due to fields at all three stations A, B and C. In this case, the beam will be deflected vertically at *a* to *b* as before. At station B, however, the beam will be deflected in the Y direction and will arrive at point *h* at station C, the amount of deflection in the Y direction being greater than in the second case due to the amplitude distortion of the field at station B. At the *point h* at station C, the beam will be further deflected upward in the X direction due to the principal deflection of the field at station C, and due to the direction distortion of this field, the beam will also be deflected to a certain extent in the Y direction just sufficient to overcome the amplitude distortion introduced at station B. Thus, the beam will arrive at the point *k* at station D, and the amount of deflection in the Y direction *j—k* when the beam is deflected an amount *j—n* in the X direction, may be made the same as the Y deflection *n—q* which occurs in the absence of fields at stations A and C.

If the beam were deflected downward in the X direction instead of upward, the fields at stations A and C would be reversed, whereas the field at station B would be the same. In this case the deflection at station A would be downward to point *d* at station B. At *d* the beam would be deflected in the Y direction to point *g* at station C, the amount of amplitude distortion being introduced at station B being the same at point *d* as at point *b*. At station C, distortion deflection will be introduced as before. In this case, the field has been reversed but due to the different position in the field, the direction of direction distortion with respect to the principal di-

rection of the field has likewise been reversed. Consequently, the direction distortion is in the proper direction to again compensate for the amplitude distortion originating at station B. Thus, the deflection *m—l* in the Y direction when the beam is deflected an amount *n—m* in the X direction is again the same as the deflection *n—q* in the absence of fields at stations A and C.

The area *l', m, j, k'*, illustrates the deflection when the beam is deflected in the Y direction opposite to the deflection in the Y direction above described. It will be apparent that the same compensation of amplitude distortion by direction distortion will occur in this region.

It will be noted that the amplitude distortion at station B is necessary to counterbalance the direction distortion at station C. It is not possible to eliminate the field at station A, deflect the beam about a point at station B and about a line at station C and thus obtain uniform deflection, without some modification of the field at B. Under these conditions no amplitude distortion would be present at either B or C, assuming, of course, a curved field at C, but some direction distortion would occur at C when a field existed thereat, even though the beam traversed the field axis, due to the displacement of the beam in the field at station C by that field as previously described. When previously deflected at A, however, the beam passes through the field axis of station C only when the field at C is zero and thus no direction distortion is incurred in this specific instance in the latter case. For this reason, in the above description when the beam passed through point *p* of station C, it was stated that no direction distortion would occur.

If the field at station A were removed, there would be some uncompensated direction distortion due to the curved field at station C. This direction distortion might be compensated by introducing amplitude distortion at station B by modifying the current causing the field at B in accordance with the current causing the field at station C, that is, electrically introducing amplitude distortion at station B. I prefer, however, to obtain the desired amplitude distortion by previously deflecting the beam at station A which is not only simpler but also has the advantage of causing parts of the total deflection in the X direction and thus minimizing any residual amplitude distortion which might be present at station C due to incorrect design. In the practice of my invention about half the deflection in the X direction may occur at station A and half at station C, but this proportion may be varied as desired over wide limits.

It will be seen that at station C, a non-uniform field has been provided and amplitude distortion in this field has been eliminated by introducing a curved field which causes some direction distortion, the magnitude of which is dependent upon the previous deflection at stations A and B. At station B, sufficient amplitude distortion in a direction perpendicular to the principal deflection at station C has been introduced to compensate for the direction distortion at station C, and the amount of this amplitude distortion is determined by the deflection at station A, the three fields cooperating to give uniform deflection in both directions regardless of the ultimate deflection which it is desired to obtain.

Thus it will be apparent that uniform deflection has been obtained by correcting for direction distortion in one field by amplitude distortion in another field, that the amount of distortion introduced in one field and corrected in another field is automatically determined by the position of the beam in the field, and that each field may be varied in strength without affecting the balancing or compensating of one type of distortion by the other, since varying the strength of one field varies the beam position and thus the compensating distortion introduced by the other field. It should be observed, however, that the beam must have the initial direction indicated to obtain this corrective action.

It will be apparent that modifications of this method are possible. For example, further deflection might be provided ahead of station A by which amplitude or direction distortion or both might be obtained and balanced out at stations B and C. Likewise the desired distortion may be obtained in other ways. It will further be apparent that other variations of the several fields might be used to revise the direction or amplitude of the deflection distortion incurred in the several fields. For example, in the actual structure shown there is, in addition to the desired amplitude distortion at station B, (field structure 7) a much smaller amount of direction distortion, which may be opposed in accordance with the invention by the proper amplitude distortion at station C (field structure 8). For the sake of simplicity, these secondary effects have not been treated in the above description, but the same principles apply in compensating for them.

In Figs. 9 to 11 there is illustrated in cooperative relation with a cathode ray tube 29 a preferred form of the unit 3 which provides the several desired fields of Fig. 2. The elements 6, 7 and 8 correspond to the similarly designated elements of Fig. 2. The field at station C, which in this particular case changes at a low frequency as compared with that at station B, is obtained by the field structure 8 similar to that of Fig. 7, which comprises a rectangular non-salient pole yoke 30, having coils 31 mounted on opposite legs of the yoke. The direction of winding of these coils is such as to form opposing fields as shown more clearly in Fig. 7, the direction of the field within the diameter of the cathode ray tube being generally parallel to the sides of the windings. The structure corresponding to that at station B of Fig. 2, comprises a rectangular yoke 32 having salient pole pieces 33 with large flat pole faces and having field coils 34 wound thereon. The field at station A of Fig. 2 is obtained by pole pieces 6 which comprise extensions from the field structure 8 and the flux due to these pole pieces is proportional to the flux of yoke 30.

As shown more clearly in Fig. 11, the field structure 7 comprises laminations which when assembled form the rectangular yoke 32 with its extending pole pieces 33. To this end, some or all of the laminations are provided with integral pole piece extensions. It will be seen that both the yoke and the pole pieces are laminated, thus reducing eddy current losses. The field coils 34 are wound about or placed over the pole pieces 33, as shown in Fig. 9.

It will be apparent that this field structure lends itself readily to commercial manufacture. The manufacture of the structure comprises simply the cutting or stamping of the laminations, the assembly of the laminations to form the complete magnetic structure, and the placing of wound coils upon the pole pieces. Of particular importance is the ease of assembly. As clearly

shown in Fig. 9, the laminations may be secured to strips 35, by means of bolts 36. The field structure may be spaced the desired distance from strips 35 by means of spacers 37.

As shown clearly in Fig. 11, the field structure 8 may likewise comprise laminations which, when assembled, form the rectangular yoke 30. The laminations may be readily cut or stamped and the coils 31 (see Figs. 9 and 10) wound and fitted upon the partially assembled laminations in simple manner. Thus, the structure lends itself readily to economical commercial manufacture.

The pole pieces 6 may each comprise several adjacent strips having one end bent inwardly adjacent some of the laminations of core 30, as shown at 38. Preferably the magnetic strips constituting the pole pieces 6 have their ends interposed between or abut against some of the laminations of core 30 and may be secured thereto by a bolt or rivet 39. In this manner, the strips are firmly secured to the core 30 and are magnetically connected to the laminations of the core so that the pole pieces 6 derive their magnetic flux from the yoke. The extending members may have inwardly turned ends as indicated at 6 in Fig. 11 and these ends may extend beyond the structure 32, as shown, or may be shorter. It is simply necessary that they serve to deflect the beam in one direction before it has traversed a substantial portion of the field of the structure 7. It will be understood, of course, that a separate field structure could be employed in place of strips 6 and that such separate structure could be arranged to set up a field bearing the desired relation to the field of structure 8.

The parts of the unit 8 may be secured together, and the unit may be attached to the strips 35 by means of bolts 40. The magnetic structure 8 may be properly spaced from the strips 35 by means of spacers 41.

Thus, there is formed a complete unit as shown in Fig. 9 which comprises the several field structures described above in connection with Fig. 2, and wherein the parts of the unitary device may be readily manufactured and assembled and the design of the field structures may be readily varied to obtain the desired results as above set forth.

The field structures may be formed of any desirable type of magnetic material, such as silicon steel or any other good grade of transformer material. If desired the entire unit may be shielded by a conductive shield, which, however, should not be positioned nearer than one or two inches from the unit.

It will be noted that with the several cores mounted as shown, the field of each is substantially independent of the other. For example, the arms 6 extending from the field structure 8 between the core 32 and the cathode ray tube 29, pass the core 32 at points wherein the magneto-motive force is the same at each pole face 33, and therefore, there is no drop in magneto-motive force between the two pole faces. Further, the field structure 8 is sufficiently well separated from the field structure 7 so that the reaction between the two, other than that above mentioned, is substantially negligible.

As previously mentioned, the field structure 8 employed at station C of Fig. 2 may comprise a salient pole structure with curved pole faces, as illustrated in Fig. 6. In Fig. 12, such a structure, adapted for use in the device of Figs. 9 to 11, is shown. This structure comprises a yoke 30a with salient pole pieces 42 having curved faces and windings 43 on the pole pieces. The coils are, of course, wound so as to form the field illustrated in Fig. 6. The arms 6 may be connected to the yoke, as before, or they may be connected to the pole pieces 42.

The device of Fig. 9, which is drawn approximately to scale, shows one experimental model of the invention which is suited for television purposes. In this example, the beam of the cathode ray gun was subject to a field of about 6,000 volts, and it was desired to deflect the beam through a total angle of about 40 degrees in the Y direction (Fig. 2), and about 30 degrees in the X direction.

In this particular model, the field structure 7 was about 4 by 3¼ inches, outside dimensions, with the pole pieces on the longer side. The pole faces of these pole pieces were flat and about 1⅝ inches long. The yoke was made up of .013 inch laminations of good grade transformer iron, similar to that used in audio transformers for radio and like apparatus, and had a cross sectional area of about 0.43 square inch. The separation between pole faces was about 1⅜ inches, and on each pole face was wound a coil having about 230 turns. The coils were connected in series and were driven by a capacitive coupling from two choke-fed type "6A3" tubes in parallel.

The field structure 8 comprised a yoke about 4 by 3 inches, outside dimensions, having a uniform cross sectional area of about 0.14 square inch. The coils were mounted on the shorter arm. Each coil comprised a multiple layer solenoid about 1½ inches long and having about 7,500 turns. As indicated, the coils were connected in series and were suitable to be capacitively coupled to the output of a single type "42" vacuum tube. This yoke was likewise made of laminations of transformer iron. The arms 6 were made of two .014 inch laminations of transformer iron, ¾ inch wide, and extended about 1½ inches beyond the edge of the structure 7. The structure 7 and the structure 8 were spaced about ¾ inch from each other. In another embodiment of the invention, the arms 6 were made of three pieces of similar stock and extended about ¼ inch beyond the edge of structure 7.

Although a specific embodiment of the invention has been illustrated and described to enable a clear understanding of the essential principles of the invention, it will be understood that the same principles may be practiced by means of modified structural forms. The invention contemplates any such modifications as may be utilized without departing from the scope of the invention as defined in the appended claims.

I claim:

1. A unitary electromagnetic device for deflecting an electron beam, comprising a field structure including a yoke and coils on said yoke, a second field structure including a yoke with salient pole pieces and coils on said pole pieces, and means for attaching said field structures together in predetermined axial spaced relation one to another, and pole pieces carried by one of said field structures and spaced from both said structures along the beam axis.

2. A unitary electromagnetic device for deflecting an electron beam, comprising a field structure including a non-salient pole yoke and coils on said yoke, a second field structure including a yoke with salient pole pieces and coils on said

pole pieces, means for attaching said field structures together in predetermined axial spaced relation one to another, and pole pieces carried by said first field structure and extending in the direction of the beam axis beyond said second field structure in spaced relation thereto.

3. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for variably deflecting said beam in one direction; magnetic means, spaced from said first magnetic means along the axis of said beam, for variably deflecting said beam in another direction substantially perpendicular to said first-mentioned direction; magnetic means, spaced from said first and said second magnetic means along the axis of said beam, for variably deflecting said beam in a direction substantially the same as one of said previously-mentioned directions; and means for supplying magnetic energy from one of said first two magnetic means to said third magnetic means.

4. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for variably deflecting said beam in one direction; magnetic means, spaced from said first magnetic means along the axis of said beam, for variably deflecting said beam in another direction substantially perpendicular to said first-mentioned direction; magnetic means, spaced from said first and said second magnetic means along the axis of said beam, for variably deflecting said beam in a direction substantially the same as said first-mentioned direction; and means for supplying magnetic energy from said first magnetic means to said third magnetic means.

5. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for deflecting said beam in one direction and for causing certain direction distortion deflection; magnetic means, spaced between said beam-forming means and said first magnetic means, for deflecting said beam in a second direction substantially perpendicular to said first direction and for causing certain amplitude distortion deflection, said amplitude distortion deflection being in such a direction as to oppose said direction distortion deflection; and means for deflecting said beam in said first direction and for variably positioning the beam during normal operation with respect to the fields of the said magnetic means, whereby said amplitude distortion deflection is caused to substantially compensate for said direction distortion deflection.

6. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for deflecting said beam in one direction and for causing certain direction distortion deflection; magnetic means, spaced between said beam-forming means and said first magnetic means, for deflecting said beam in a second direction substantially perpendicular to said first direction and for causing certain amplitude distortion deflection, said amplitude distortion deflection being in such a direction as to oppose said direction distortion deflection; and means spaced between said beam-forming means and said second magnetic means, for deflecting said beam in said first direction and for variably positioning the beam during normal operation with respect to the fields of the said magnetic means, whereby said amplitude distortion deflection is caused to substantially compensate for said direction distortion deflection.

7. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for deflecting said beam in one principal direction and for causing certain direction distortion deflection, said deflecting means comprising a magnetic non-salient pole yoke having coils on said yoke; magnetic means, spaced between said beam-forming means and said first magnetic means, for deflecting said beam in a second principal direction substantially perpendicular to said first direction and for causing certain amplitude distortion deflection in such direction as to oppose said direction deflection distortion, said second magnetic means comprising a magnetic field structure having salient pole pieces with flat faces and coils on said pole pieces; and means, spaced between said beam-forming means and said second magnetic means, for deflecting said beam in said first principal direction and for variably positioning the beam during normal operation with respect to the fields of the said magnetic means, whereby said amplitude distortion deflection is caused to substantially compensate for said direction distortion deflection.

8. In cathode ray deflecting apparatus; means for forming an electron beam; magnetic means for deflecting said beam in one principal direction and for causing certain direction distortion deflection, said deflecting means comprising a magnetic field structure having pole pieces with curved faces and coils on said pole pieces; magnetic means, spaced between said beam-forming means and said first magnetic means, for deflecting said beam in a second principal direction substantially perpendicular to said first direction and for causing certain amplitude distortion deflection in such direction as to oppose said direction distortion deflection, said second magnetic means comprising a magnetic field structure having salient pole pieces with flat faces and coils on said pole pieces; and means, spaced between said beam-forming means and said second magnetic means, for deflecting said beam in said first principal direction and for variably positioning the beam during normal operation with respect to the fields of the said magnetic means, whereby said amplitude distortion deflection is caused to substantially compensate for said direction distortion deflection.

9. In cathode ray deflecting apparatus; means for forming an electron beam; an electromagnetic field structure for deflecting said beam in one principal direction; a second electromagnetic field structure, axially spaced from said first field structure, for deflecting said beam in a second principal direction substantially perpendicular to said first direction; and magnetic pole pieces, carried and energized by said first field structure and spaced from both said field structures on the side of said second structure opposite said first structure, for deflecting said beam in said first principal direction.

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