

Feb. 12, 1952

R. R. LAW ET AL

2,585,798

BEAM DEFLECTION TUBE AMPLIFIER

Filed Dec. 22, 1949

2 SHEETS—SHEET 1

Fig. 1

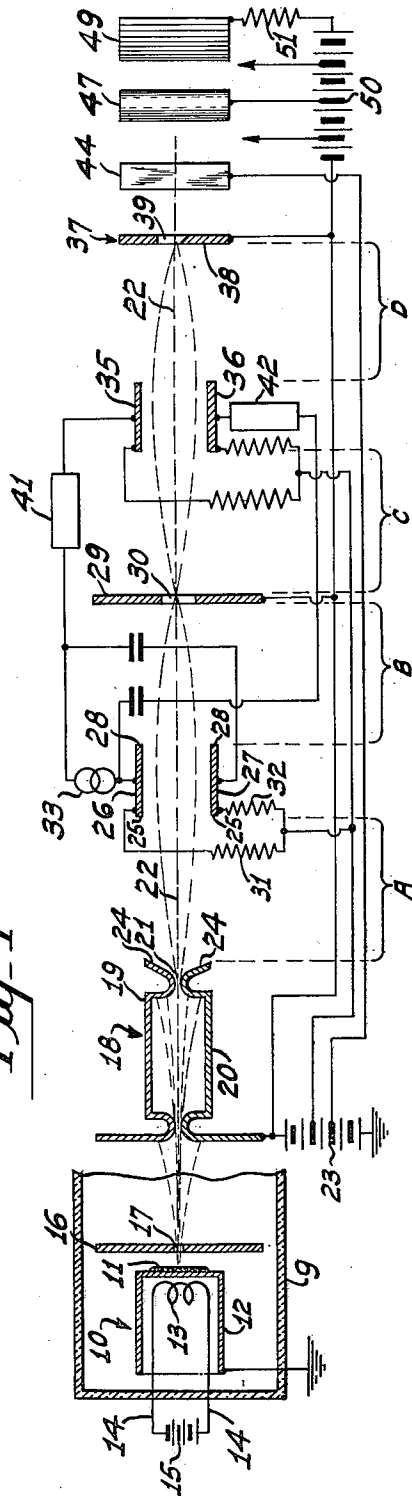


Fig. 2

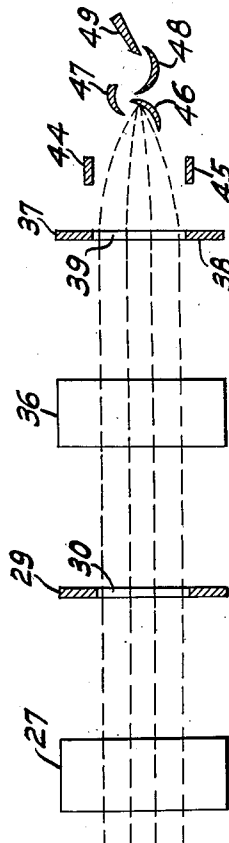
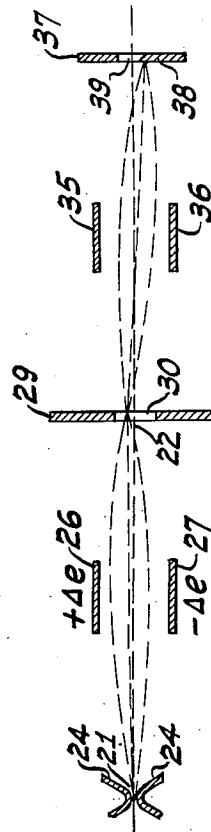


Fig. 3



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2 SHEETS—SHEET 2

*Fig-4*

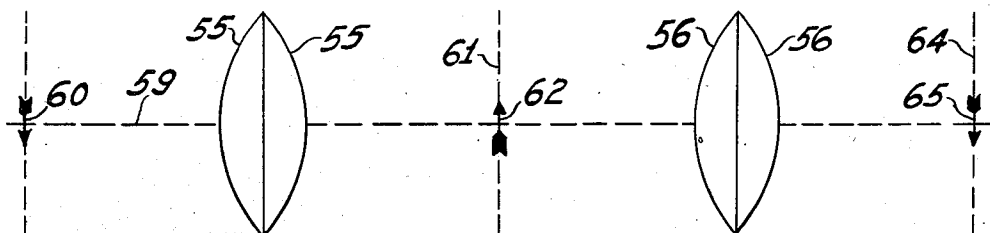


*Fig-5*

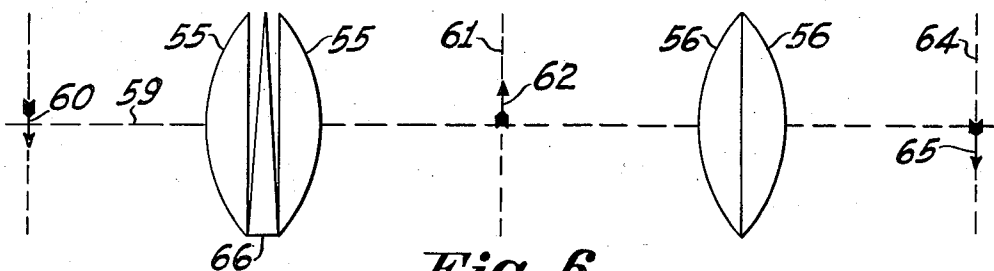


*Fig-6*

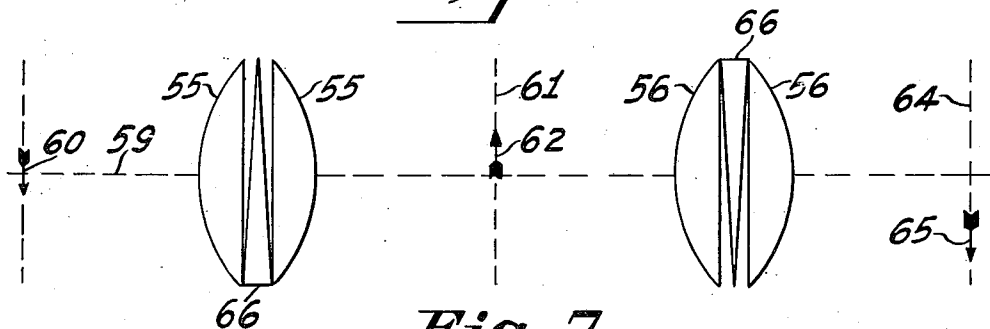
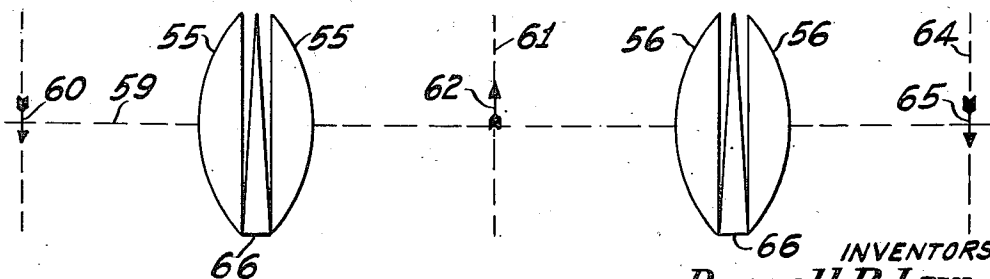


*Fig-7*



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## UNITED STATES PATENT OFFICE

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## BEAM DEFLECTION TUBE AMPLIFIER

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Application December 22, 1949, Serial No. 134,386

15 Claims. (Cl. 315-17)

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This invention relates to improvements in beam deflection tube amplifiers. More particularly it relates to improvements therein for reducing the effects of spurious deflection fields.

There are many applications in which it would be very advantageous to use a beam deflection tube because of its broad operating band; its high input impedance; its extreme sensitivity; its particular suitability to the inclusion of an electron multiplier; and its low coupling (primarily electron coupling) between deflection elements located at different points along the beam. Despite its desirable characteristics, this tube has not come into widespread use because of a number of difficulties. One of these is that its great sensitivity causes it to respond to spurious ambient fields of ordinarily negligible magnitudes. In practice these are usually found to be magnetic fields. It has been proposed to use two electron beams so arranged in the same tube that separate output system current changes resulting from intentionally-produced deflections of the respective beams will supplement each other whereas corresponding current changes resulting from spurious deflections will tend to cancel each other. Apart from the costliness of a two-gun tube, it will not produce exact cancellation unless the characteristics of the two guns are identical.

It has also been proposed to make the tube envelope in the form of a magnetic shield. However such a shield is likely to acquire magnetism of its own, i. e., residual magnetism; it affords no protection against internally-generated fields such as those produced by the cathode heater winding when energized with A. C.; and it prevents the use of a small permanent magnet affixed to the outside of the envelope as a means for making final alignment of the beam.

Accordingly, the principal object of the present invention is to obviate the foregoing and other less apparent objections to electron discharge devices of the general character described.

It is a further object of the present invention to provide an improved beam deflection amplifier of the type employing but a single beam, and one which shall be substantially immune to stray fields and this too without the use of auxiliary magnetic or electrostatic shielding.

The invention will be described in greater detail with reference to the two sheets of the drawings in which:

Fig. 1 is a diagrammatic representation of an embodiment of the present invention including a representation of a sectional view taken along a central longitudinal axis of the tube;

Fig. 2 is a representation of a sectional view of

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part of the tube represented in Fig. 1 taken in a plane containing the same central axis but perpendicular to the plane of the view of Fig. 1;

Fig. 3 shows the nature of the beam deflections which will be occasioned in the structure of Fig. 1 under certain operating conditions; and

Figs. 4, 5, 6, and 7 are representations of light-optical systems which are helpful in explaining the principles of operation of the present invention.

In general, according to the present invention the foregoing and other objects are attained by projecting the electron beam along a straight path through two regions, each containing an electron-optical and a deflection system. A small aperture through which electrons are projected from the electron gun is the "object" seen by the first optical system which produces an inverted image of it in a plane separating the two regions. This image will move in said plane as the result of any deflection of the beam in the first region which deflection, of course, may result from spurious fields, or from useful ones (due to signals applied to the first deflection system) or from both. The second optical system produces an inverted image of the first image at the "knife edge" of a masking electrode. The beam current which passes over the knife edge to the output of the tube will vary in accordance with movements of the second image. As will be explained in detail, the second optical system will effectively invert the direction of any deflection of the beam which occurred in the first region. Since in general a spurious field will deflect the beam in the same direction in the second region as in the first and since this later deflection is not inverted the total undesired deflection will be the difference between that occurring in the first region and that occurring in the second region, i. e., substantially no deflection. On the other hand, because the inputs to the two deflection system are cross-connected so that a useful signal will influence the beam in opposite senses in each region, the total useful deflection will be the sum of the inverted useful deflection occurring in one direction in the first region and the uninverted deflection occurring in the opposite direction in the second region. Therefore the beam current which will pass over the knife edge to the output system will be controlled only by useful signals. While the output system may simply consist of a collecting anode, in preferred embodiments it will include an electron multiplier which is interposed between the knife edge and the collecting anode.

Fig. 1 represents an amplifier circuit including

a beam deflection tube which may be constructed by using design details and assembly techniques known to the prior art, e. g., as in U. S. Patent 2,434,713 to C. W. Mueller and in the co-pending application of C. W. Mueller Serial No. 759,769, filed July 9, 1947, now U. S. Patent No. 2,551,810, granted March 8, 1951, which are both assigned to the same assignee as the present application. Because of this and to simplify the drawing this tube is represented schematically instead of with all of many structural features which will be useful in practice.

The tube represented in Fig. 1 is enclosed in an evacuated envelope 9 and comprises a cathode 10, having an elongated emissive coating 11 extending across the intended planar axis of the beam so as to supply electrons which can be drawn (by an appropriate accelerating and focusing system) to form a thin, wide ribbon- or sheet-shaped beam. In the particular embodiment shown herein the cathode 10 comprises a rectangular "thimble" 12 having the coating 11 deposited along the center of its closed end and a heater winding 13 mounted adjacent the inside surface of said end. The heater winding 13 is shown to have a pair of leads 14 connected to the opposite terminals of a source of potential 15. At a short distance in front of the coating 11 there is mounted a cathode shield 16 having a rectangular slit 17 aligned with and parallel to the long axis of the coating 11. Beyond the shield 16 in the intended direction of beam travel is an aperture assembly 18 of a type which is known to the art and is described both in the above-mentioned copending application and in an article, "Beam-Deflection Mixer Tubes for U. H. F." by E. W. Herold and C. W. Mueller which appeared in the May 1949 issue of "Electronics." This assembly comprises top and bottom stampings 19 and 20 having closely spaced opposed surfaces defining two slit apertures for forming the electrons which are drawn therethrough into a thin sheet. This function for assembly 18 is indicated by the dotted lines used in this figure to represent the paths of both fringing electrons which do not pass through the slits and electrons moving near the tube axis which do pass therethrough. The slit 21 may be looked upon as a thin-line virtual cathode which extends across the width of the intended planar axis 22 of the beam and from which electrons emerge moving along paths nearly parallel to each other and very close to the planar axis. Actually of course, since each slit has a finite width, fringing electrons which pass through a cross-over point between the slits and which are not intercepted at the second slit 21 will be slightly divergent as they emerge from the assembly 18.

In the operation of the electron gun consisting of the elements thus far described, a source of potential 23 will be connected between the cathode 10 and the assembly 18 to provide an electron accelerating field. For example the assembly may be polarized at +300 volts while the cathode 10 is grounded. Immediately to the right of the assembly 18 the beam will tend to thicken due to the divergence of some of the electrons and space charge effects. However, to attain a useful order of sensitivity it is essential that the beam be very thin at the point where it crosses the knife edge. For this reason means are provided, as is customary, for focusing the divergent electrons in the region beyond the slit 21 to produce an image of the slit along the knife edge. Because of the fact that the electron gun herein

is intended to produce a ribbon- or sheet-like beam rather than a pencil-like beam, the electrostatic focusing system used for this purpose comprises cylindrical electron optics, as distinguished from spherical ones. Moreover, since, as will be seen, it is necessary according to the present invention to produce two successive images of the slit 21, two successive cylindrical electron optical systems are employed, and, in actuality, it is the second image thereof which is positioned along the knife edge. The elements constituting the first optical system include two groups, one consisting of the forward facing surfaces 24 of the aperture assembly 18 in combination with the rearward facing edges 25 of a pair of deflection plates 26 and 27 (which together afford a first optic which has an over-all condensing effect over zone A) and the other consisting of the forward facing edges 28 of said plates in combination with the rear surface of a boundary electrode 29 (which together afford a second condensing optic effective over zone B). In the particular arrangement shown herein each of the plates 26 and 27 is connected to a lower potential point of the source 23 than the point to which the assembly 18 is connected. It is because of this that in a manner which is well known a cylindrical condensing "electron lens" will be produced in zone A. This first lens or optic will influence the electrons, as they move through zone A, to progressively reduce the initial divergence of their paths until they become substantially parallel in the region between the plates 26 and 27. By this time, as shown in Fig. 1, the beam will have become considerably thickened. Since the region central between these plates will be substantially free of fringing fields from zones A and B, the electrons will drift therethrough substantially rectilinearly.

It will be noted that the electrode 29 is connected to the same potential point of the source 23 as is the assembly 18. If the spacing between the edges 28 and the electrode 29 is properly chosen the condensing effect of the electron optic in zone B will be to produce a first image of the slit 21 in a first image plane parallel to the electrode 29 and extending across a rectangular aperture 30 which is appropriately formed in it to permit passage of the beam. In the absence of any deflecting influences the center of the first image will coincide with a transverse section of the planar axis 22 at the first image plane, i. e., at the electrode 29. This image will, of course, be an inversion of the object, i. e., of the slit 21. Each of the plates 26 and 27 is connected to the source 23 over a respective resistor 31 and 32 of such value that the plates are sufficiently isolated from one another and from the power supply to permit a signal source 33 to establish a useful deflection gradient between the plates without being unduly loaded.

Beyond the boundary electrode 29 there is a second set of deflection plates 35 and 36 and beyond these plates there is a knife edge electrode 37 having a back surface 38 which functions in the optical system of the second region in the same manner as the back surface of the boundary electrode 29 in the optical system of the first region. However, in certain of their structural details the boundary electrode 29 and the knife edge electrode 37 will differ from each other. For example the aperture 30 of the boundary electrode 29 has to extend sufficiently above and below the planar axis 22 not only to pass all the quiescent beam at its first image

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point (the beam, of course, has a finite thickness despite the fact that it is brought to as sharp a focus as possible) but also to provide the additional clearance required because of its dynamic vertical deflections, whereas the aperture 39 need not extend above the planar axis for much more than about  $\frac{1}{2}$  or  $\frac{2}{3}$  of the thickness of the second image, i. e., to provide clearance for the upper portion of the beam which is intended to pass on to the output system, and it should not extend below the planar axis 22 at all, in fact the lower edge of the aperture 39 should preferably be a sharp "knife edge" positioned along a transverse section of the planar axis 22 at the second image plane to intercept varying amounts of the lower portion of the beam in accordance with the overall deflections thereof.

The functionings of the elements constituting the second optical system as an arrangement of optics for producing a second image of the slit 21 corresponds to those of the elements constituting the first optical system. However, this is not strictly true of the functionings of some of these elements as a second deflection system. This is due to the fact that the connections between the signal source 33 and the deflection plates 35 and 36 are opposite to those between it and the deflection plates 26 and 27. Therefore a voltage which causes a deflection of the beam in one direction as it passes between the plates 26 and 27 will cause a deflection thereof in the opposite direction as it passes between the plates 35 and 36. Due to the fact that it takes electrons a finite time to move from the first deflection region to the second, delay means 41 and 42 (each of which may consist of a relatively long transmission line or of a plurality of small series inductors and shunt capacitances in a relatively compact arrangement constituting an artificial "delay line") are respectively included in the connections between the plates 35 and 36 and the source 33. In this way an instantaneous voltage which is applied to the plates 26 and 27 as a given electron is passing between them will not get to be applied to the plates 35 and 36 until the same electron has reached and is passing between them. Because of this arrangement the transit time of the beam through zones B and C does not prevent this tube from being operative at very high frequencies. Moreover, in practice it has been found that it retains its operativeness over a very wide band of frequencies. Of course, as is known, the transit time of an electron through each deflection region (this being a function of the length of the plates along the axis 22 and the speed of the beam) is a frequency limiting factor and should be considered in the usual way.

Beyond their cross-over at the first image plane the beam electrons will tend to diverge a second time. However, as has already been explained with respect to the first electron optical system they will be controlled in zone C so as to enter into the region between the plates 35 and 36 along substantially parallel paths which are somewhat spread apart and in zone D they will be made to converge to produce a second image at the knife edge of the electrode 37.

Assuming that no input signal is being applied to the deflection systems and that no spurious fields are acting upon the beam its upper half will clear the knife edge of the electrode 37 and move toward the output system.

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If desired the output system can simply be a collector electrode, i. e., an anode. However, in preferred embodiments an electron multiplier will be employed in the output system to take advantage of the fact that a beam deflection tube is particularly well adapted to inclusion thereof. The reason for this is that in such a tube very high ratios of transconductance to average current can be attained.

The arrangement of the electron multiplier will be best understood with reference to Fig. 2 since some of its elements do not appear in the section of the tube represented in Fig. 1. The same is true of a beam-narrowing system between the knife edge and the multiplier. After passing the knife edge the beam passes between a pair of beam-narrowing electrodes 44 and 45 between which it is compressed to a sufficiently narrow width so that all of its electrons will impinge upon the first dynode 46 of the multiplier. This is an improvement over arrangements in which the long axis of each of the dynodes is parallel to the width of the sheet-shaped beam. In such arrangements, the deflections of the beam cause the electrons which clear the knife edge to impinge upon the curved surface of the first dynode at a widely varying average angle of incidence and on a substantially changing area thus affecting the gain of the multiplier and distorting the output signal. In the present arrangement deflections are lengthwise of the first dynode and therefore do not produce such effects.

In the example shown herein the multiplier includes two more dynodes, 47 and 48 respectively, which may be made of known suitable materials and positioned in a known suitable manner with respect to the first dynode. The secondary emission of the third dynode 48 is collected on a collector anode 49. In order to polarize the successive stages of the multiplier at ascending potentials a source of direct potential 50 is connected in series with the source 23. In accordance with the customary practice different potential points of the source are connected to the respective dynodes and to the anode and a load resistor 51 is connected in series with the anode return circuit.

Figure 3 represents the path of the electron beam when a deflection signal *e* is applied between the plates 26 and 27 of the Fig. 1 amplifier without being applied to the second set of plates and when the path of travel of the beam is free of any spurious fields. Assuming such a polarity for *e* that plate 26 is more positive than plate 27 each beam electron in passing between these plates will acquire a drift component in the upward direction in the drawing, i. e., its path will have an upward tilt with respect to the tube axis. Upon emerging from this deflection region and as they drift toward the end of the first region the electrons will continue their upward drift so that the first image will be produced in the first image plane at a position somewhat above the planar axis 22.

As to the second electron optical system the first image is simply an object which happens to be displaced upwards from the axis 22 and which it therefore will image in the second image plane at a corresponding distance below the axis (assuming that the magnification of the two optical systems is equal). It will be noted from the foregoing that in effect any overall angular tilt imparted to the beam in the first region is inverted and doubled by the optical system of the second

region. Assuming a spurious field which acts in the same direction in both regions, the effective angular tilt which it will impart to the beam in the second region will be substantially equal and opposite to the increase in magnitude which will be acquired, during inversion in the second optical system, by the effective angular tilt which the same spurious field imparted to the beam in the first region, i. e., total effective angular tilt  $= \theta - 2\theta + \theta = 0$ . Therefore two increments of spurious angular deflection resulting from the continuing influence of the spurious field over all of the path of travel of the beam will be made to cancel each other.

It is apparent from the foregoing that the arrangement disclosed herein will be capable of producing an output which varies in accordance with an input signal but is not substantially influenced by spurious fields. Moreover this will be true even if the signal is only applied between the first set of plates (so that in effect the only function of the second set of plates is as a part of the second optical system). However, if, as shown in Fig. 1, the signal is also applied to the second set of plates, more useful deflection can be obtained and therefore an increase in the sensitivity of the tube.

Fig. 4 represents an end view of a light-optical system comprising two pairs of plano-convex cylindrical lenses having a common planar axis 59 with the lenses of each pair placed back-to-back to constitute a double-convex lens and with the double-convex lenses spaced from one another along the axis so that the light-optical system corresponds to the electron optical system of Fig. 1. The double convex lenses 55 and 56 correspond respectively to the first and second optical systems. Fig. 4 illustrates how an object 60 may be inverted in a first image plane 61 as shown at 62 and erected in a second image plane 63 as shown at 64, i. e., how each double-convex lens will invert the displacement from axis 59 of any elementary area of the object it sees without regard to how it got there.

In Fig. 5 there is represented a variation of Fig. 4 in which the first pair of plano-convex lenses is separated by a thin prism 65 which deflects upward the substantially parallel bundle of rays between them so that the effect is the same so far as the second double-convex lens is concerned as that which would exist in the arrangement of Fig. 4 if the object 60 were physically positioned below the axis 59. In its effect the introduction of the prism between the first pair of plano-convex lenses may be considered as equivalent to a downward displacement of the object while the axis of the first double-convex lens remains stationary, or to an upward tilting of the axis of the first double-convex lens, or to an upward tilting of the image axis of the first double-convex lens with respect to its object axis. In the analogy of Fig. 5 the left and right plano-convex lenses of the double-convex lens 55 correspond respectively to the condenser electron optics in the zones A and B respectively; the prism 65 corresponds to the deflection means 25, 26; and left and right plano-convex lenses of the double-convex lens 56 correspond respectively to the electron optics in the zones C and D.

Fig. 6 includes a second prism 66 to extend the light-optical analogy to represent the operation of this system when a useful signal is applied in opposite sense to the two deflection systems. It will be noted that the overall displacement, i. e., the displacement of the second image, is twice as

great as the displacement of the first image. Similarly Fig. 7 extends the analogy to represent the operation of the system when a spurious deflection field acts upon the beam in the same direction over all of its path of travel illustrating how the second image is produced without any displacement from a position which corresponds to that of the object with respect to the axis.

From the foregoing it is apparent that the present invention provides an improved beam deflection amplifier and one which is substantially immune to stray electrostatic and electromagnetic fields.

What we claim as new is:

1. A beam deflection tube comprising an evacuated envelope, within the envelope an electron gun for producing a beam of electrons along a rectilinear axis and forming it with at least one small cross sectional dimension where it passes through an object plane normal to said axis, between said object plane and an image plane positioned further along said axis and normal thereto a group of electrodes affording when polarized at appropriate potentials a first electron optical system for producing in the image plane an image of the cross section of the beam in said object plane, said electrodes including a pair of plates positioned on opposite sides of said axis in the direction of said cross sectional dimension for producing in response to a deflection gradient between the plates displacement of said image in said image plane in one of two opposite directions corresponding to said dimension, between said image plane and a second image plane positioned further along said axis and normal thereto a second group of electrodes affording when polarized at appropriate potentials a second electron optical system for producing in the second image plane an image of the first image, whereby for any displacement of said image in one direction in said first-mentioned image plane the second image will be displaced in the opposite direction in the second image plane, a knife-edge electrode positioned at the second image plane and having its knife edge extending across said axis to intercept a portion of said beam which varies according to displacements of the second-mentioned image in either of two directions corresponding to said small dimension, means connectable to an external signal source for applying deflection signals between said plates, and an electron receiving anode positioned beyond the knife-edge electrode to collect electrons in accordance with what portion of the beam is not intercepted thereby.

2. A beam deflection tube comprising an evacuated envelope, within the envelope an electron gun for producing a beam of electrons along a rectilinear axis and forming it with at least one small cross sectional dimension where it passes through an object plane normal to said axis, between said object plane and an image plane positioned further along said axis and normal thereto a group of electrodes affording when polarized at appropriate potentials a first electron optical system for producing in the image plane an image of the cross section of the beam in said object plane, said electrodes including a pair of plates positioned on opposite sides of said axis in the direction of said cross section dimension for producing in response to a deflection gradient between the plates displacement of said image in said image plane in one of two opposite directions corresponding to said dimension, between said image plane and a second image plane

positioned further along said axis and normal thereto a group of electrodes affording when polarized at appropriate potentials a second electron optical system for producing in the second image plane an image of the first image, whereby for any displacement of said image in one direction in said first-mentioned image plane the second image will be displaced in the opposite direction in the second image plane, a boundary electrode extending across said axis between the first and second optical systems to shield each thereof from electric fields existing in the other during the operation of the tube, the boundary electrode having an aperture surrounding said axis and large enough to permit passage of substantially all the beam electrons even when the first-mentioned image is displaced from said axis in either of said directions by predetermined amounts, a knife edge electrode extending across said axis to intercept a portion of said beam which varies according to displacements of the second-mentioned image in either of two directions corresponding to said small dimension, means connectable to an external signal source for applying deflection signals between said plates, and an electron-receiving anode positioned beyond the knife edge electrode to collect electrons in accordance with what portion of the beam is not intercepted thereby.

3. A beam deflection amplifier comprising a beam deflection tube including an evacuated envelope, within the envelope an electron gun for producing a beam of electrons along a rectilinear axis and forming it with at least one small cross sectional dimension where it passes through an object plane normal to said axis, between said object plane and an image plane positioned further along said axis and normal thereto a first group of electrodes affording when polarized at appropriate potentials a first electron optical system for producing in the image plane an image of the cross section of the beam in said object plane, said first group of electrodes including a pair of plates positioned on opposite sides of said axis in the direction of said cross sectional dimension for producing in response to a deflection gradient between the plates displacement of said image in said image plane in one of two opposite directions corresponding to said dimension, between said image plane and a second image plane positioned further along said axis and normal thereto a second group of electrodes affording when polarized at appropriate potentials a second electron optical system for producing in the second image plane an image of the first image, whereby for any displacement of said image in one direction in said first-mentioned image plane the second-mentioned image will be displaced in the opposite direction in the second image plane, said second group of electrodes including a second pair of plates positioned on opposite sides of said axis in the direction of said cross sectional dimension for producing in response to a deflection gradient between the plates displacement of said second-mentioned image in said second plane in the other of said two opposite directions, a knife-edge electrode positioned at the second image plane and having a knife edge extending across said axis to intercept a portion of said beam which varies according to displacements of the second-mentioned image in either of said opposite directions and an electron-receiving anode positioned beyond the knife-edge electrode to collect electrons in accordance with what portion of the beam is not intercepted thereby; and a circuit for applying

a deflection signal between said first pair of plates to establish a gradient in a first direction therebetween and for applying the same signal between the second pair of plates, after a delay substantially equivalent to the transit time of an electron along the beam axis from the first pair of plates to the second, to establish therebetween a deflection gradient in the direction opposite to said last-mentioned gradients.

4. A beam deflection tube as in claim 1 in which said electron gun is adapted to produce a sheet-shaped beam, said cross sectional dimension being the thickness dimension thereof and the beam being relatively wide with respect to its thickness, and further comprising electrodes which are positioned near opposite edges of the beam and extend in the direction of its thickness dimension to form, when polarized at appropriate potentials, a beam narrowing system for reducing the width of the portion of the beam which passes over and beyond said knife-edge whereby electrons from opposite edges of the beam converge toward a predetermined point, an electron multiplier interposed between the beam narrowing system and the electron-collecting anode and having a first dynode positioned near said point to receive the reformed beam.

5. A beam deflection tube comprising an electron gun for producing a thin beam of electrons along a rectilinear axis, said gun including means for limiting the cross section of the beam in an object plane normal to said axis and near the output of the gun to have at least one small transverse dimension, in a first region surrounding said axis between the object plane and an image plane electron optical means for producing in the image plane an image of said cross section of the beam, said optical means having an axis normally coincident with the beam axis in the first region, in a second region surrounding said beam axis between said image plane and a second image plane second electron optical means for producing in the second image plane an image of said first-mentioned image, said optical means having an axis normally coincident with the beam axis in the second region, and means effective in one of said regions in response to a deflection signal to effectively tilt the axis of the optical means therein away from the beam axis in a direction which depends on the polarity of the signal and corresponds to said small transverse dimension, and output means for receiving a portion of the electron current of the beam which varies in accordance with displacements of the center of the second image from said axis.

6. A beam deflection tube as in claim 5 and also comprising means effective in the other of said regions in response to the same deflection signal to effectively tilt the axis of the optical means therein away from the beam axis in the opposite direction.

7. A beam deflection discharge device comprising an electron gun for producing a sheet-shaped beam with a relatively small thickness-dimension and a relatively large width-dimension, said gun including an electrode formed to define a slit aperture through which the beam emerges with a predetermined thinness and is projected along a planar axis for the beam if it is not influenced by deflection fields, spaced from said electrode along said axis in the direction of electron travel a knife edge electrode positioned crosswise to said planar axis and having an electron-intercepting knife edge extending into the quiescent beam in the direction of its thickness dimension, elements adapted when polarized at

appropriate potentials to afford at least one electron optical system intermediate said first-mentioned electrode and said knife edge electrode for producing at said knife edge an image of the cross section of the beam at said slit aperture, whereby some of the beam electrons are projected beyond the knife edge, beyond the knife edge beam-narrowing means including a pair of electrodes positioned near opposite edges of the beam and extending in the direction of said thickness-dimension for reducing the beam in its width-dimension, and an output system positioned beyond the beam narrowing system along said axis and including an electrode adapted to intercept the narrowed beam.

8. A beam deflection tube comprising an electron gun for producing a thin beam of electrons along a rectilinear axis, said gun including means for limiting the cross section of the beam in an object plane normal to said axis and near the output of the gun to have at least one small transverse dimension, in a first region surrounding said axis between the object plane and a boundary plane means for causing the beam where it passes through the boundary plane to have a cross section of substantially the same size and shape as said cross section in the object plane, in a second region surrounding said beam axis between said boundary plane and an image plane electron optical means for producing in the image plane an image of the beam cross section in the boundary plane and means effective in one of said regions in response to a deflection signal to effectively tilt the axis of the beam therein away from said rectilinear axis in a direction which depends on the polarity of the signal and corresponds to said small transverse dimension, and output means for receiving a portion of the electron current of the beam which varies in accordance with displacements of the center of said image from said rectilinear axis.

9. A beam deflection tube as in claim 8 and comprising a boundary electrode extending across said axis at said boundary plane for shielding each of said regions from fields existing in the other during the operation of the tube, the boundary electrode having an aperture surrounding said axis to permit passage of the beam.

10. A beam tube comprising an electron gun for projecting a beam of electrons through two regions along a normally straight path, said gun including means for blocking fringing electrons of the beam to limit to a small size the cross-section thereof at its point of emergence from the gun, an output system at the end of said path for receiving a varying amount of beam current according to deflections of the beam from said path at a predetermined reference therealong, means in the first region for focusing the beam electrons to produce a cross-over thereof between said two regions, means in the second region for focusing the beam electrons to produce a second cross-over thereof near said reference, a masking electrode for intercepting a predetermined portion of the beam at said second cross-over when it follows said straight path, and means responsive to an input signal to deflect said beam from said path in one of said regions.

11. A beam tube comprising an electron gun formed with a small beam-defining aperture and adapted to project a beam of electrons through the aperture along a normally straight path, a boundary electrode having an opening through which said beam is projected, the electrode being

positioned at an intermediate point along said path to divide it into two regions, means for producing a varying output current from the tube according to deflections of the beam from said path at a predetermined reference therealong, means in the first region for focusing the beam electrons to produce an image of said aperture at said opening, means in the second region for focusing the beam electrons to produce a second image of said aperture near said reference, a masking electrode for intercepting a predetermined portion of the beam at its second image point when it follows the normally straight path whereby an unintercepted portion will pass an edge of the masking electrode and continue to said means producing an output current, and means responsive to an input signal to deflect said beam from said path in one of said regions.

12. A beam deflection tube comprising an evacuated envelope having an electron-optical axis and containing a source of a beam of electrons and a target electrode disposed adjacent to opposite ends of said axis, said source including an apertured electron-current-masking electrode for limiting the cross-section of said beam to a small size at a point of emergence from the source, electron-optical means for establishing in succession inverted and re-inverted virtual images of said source adjacent to said axis in the space between source and said target electrode, a masking electrode having an edge disposed contiguous to said axis adjacent to the focal point of said reinverted image, and beam-deflecting means for moving said beam and hence said focal point with respect to said masking electrode whereby to vary the relative quantity of electrons impinging upon said masking and target electrodes.

13. A beam deflection tube as set forth in claim 12 and wherein said axis is a planar axis, said source comprises an electron gun adapted to project a ribbon-like beam of electrons along said axis and said edge of said masking electrode extends in the direction of the width dimension of said beam.

14. A beam deflection tube as set forth in claim 13 and wherein said target electrode comprises a dynode having an emissive surface disposed at right angles to the width dimension of said beam.

15. A beam deflection tube as set forth in claim 12 and wherein said electron-optical means comprises an even number of electron optical systems in spaced relationship along said axis, and including an apertured boundary electrode disposed between adjacent optical systems for shielding each from electrostatic fields of the other.

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