

March 7, 1967

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3,308,335

ELECTROSTATICALLY FOCUSSED ELECTRON IMAGE TUBES

Filed March 28, 1963

2 Sheets-Sheet 1

FIG. 1.

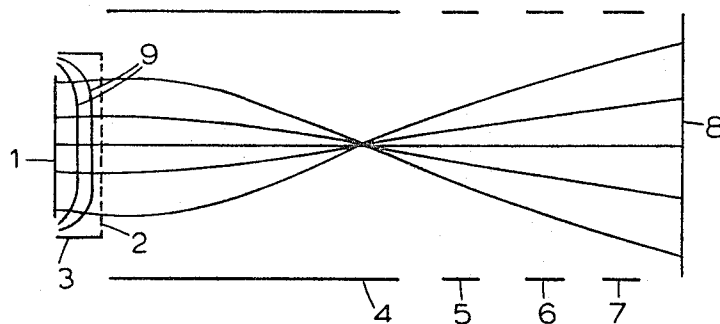
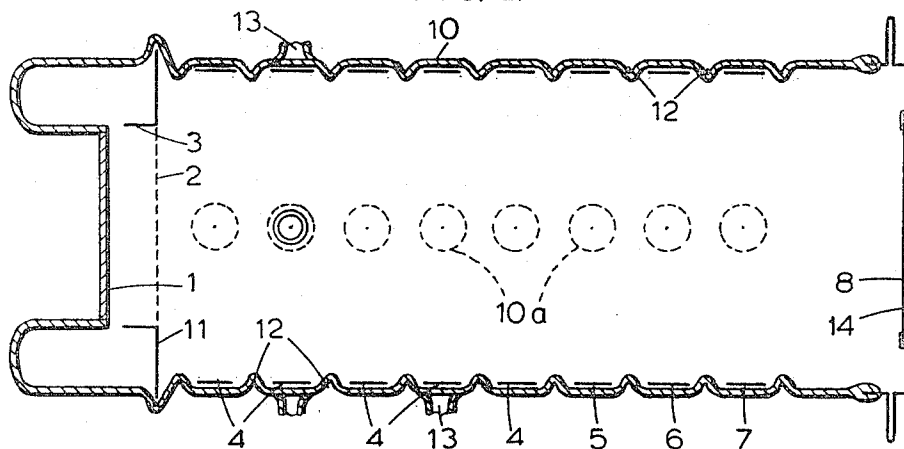


FIG. 2.



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FIG. 3.

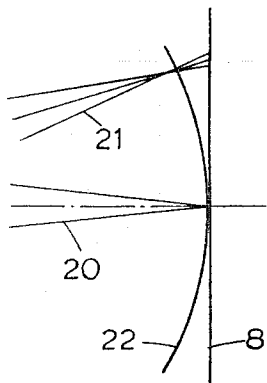


FIG. 4.

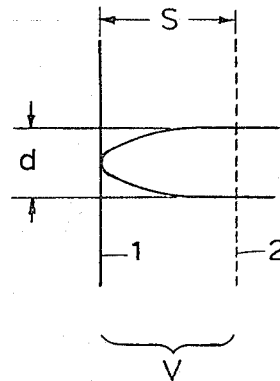
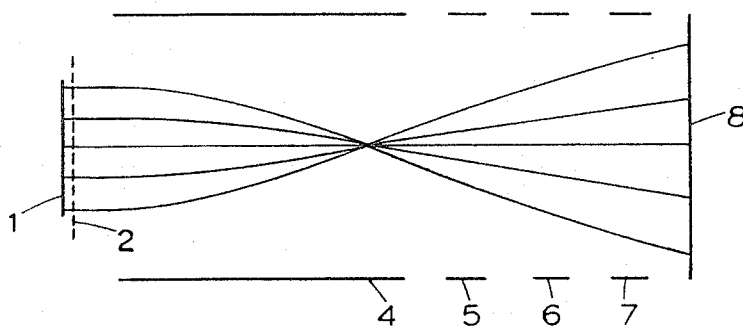


FIG. 5.



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ELECTROSTATICALLY FOCUSED ELECTRON IMAGE TUBES

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12,005/62

4 Claims. (Cl. 315—31)

This invention relates to electron discharge tubes employing electrostatic focusing.

In some forms of electron discharge tubes an electron image has to be focused onto a target surface by electrostatic focusing means, but it is found that the focusing system frequently causes considerable curvature of the electron image to occur so that if a planar luminescent screen or other target surface for the electrons is employed the electrons at said screen may be in focus at one position but considerably out of focus at another position.

The object of the invention is to provide an improved electron discharge tube employing electrostatic focusing wherein the above indicated disadvantage can be alleviated.

More precisely the object of the present invention is to improve the focusing of an electron discharge tube comprising an evacuated envelope, a substantially flat image electron-emissive surface, a substantially flat target for electrons emitted from said emissive surface said surface and target being spaced one from the other, and a converging electrostatic focusing means for focusing pencils of electrons emitted from said surface in the vicinity of said target.

A further object of the invention is to provide, in a tube of the kind described in the preceding paragraph, an auxiliary focusing means which reduces curvature of the image field of the converging focusing means, or reduces the divergence of the electron pencils from the respective points on the image field at which they are brought to focus, or reduces both the curvature of the image field and the divergence of the electron pencils.

In order that the invention may be clearly understood and readily carried into effect it will now be more fully described with reference to the accompanying drawings, in which:

FIGURE 1 shows diagrammatically an arrangement of electrodes for use in an electron discharge tube employing electrostatic focusing and according to one embodiment of the invention,

FIGURE 2 shows a practical embodiment of the arrangement of the invention shown in FIGURE 1,

FIGURES 3 and 4 are diagrams explanatory of the invention, and

FIGURE 5 illustrates a modification of the tube illustrated in FIGURES 1 and 2.

The invention will be described with reference to the drawings, as applied to an image converter tube in which the electron emissive surface is a photo-electron emissive cathode and the target is a luminescent screen on which an intensified image of an optical scene incident on said cathode is required to be set up. As shown in FIGURE 1, the photo-electron emissive cathode is a planar electrode indicated by reference 1 and has closely spaced therefrom an electron pervious electrode in the form of a fine pitch mesh 2 of high transparency. The periphery of the mesh 2 is connected to a short conducting cylindrical electrode 3 extending towards the cathode 1 as shown, the mesh 2 and electrode 3 forming auxiliary focusing means. A plurality of cylindrical focusing electrodes 4, 5, 6 and 7 are provided spaced apart along the

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tube and beyond the end of the last electrode 7 is disposed the luminescent screen 8.

In operation of the tube shown in FIGURE 1 the mesh 2 and electrode 3 are maintained at a high potential with respect to cathode potential, for example about 2 kv., the electrode 4 is maintained at a low potential, for example near cathode potential or negative to cathode, the electrodes 5, 6 and 7 are maintained at high potentials which may, for example be 4 kv., 6 kv. and 8 kv. respectively (or in similar ratio) and the luminescent screen 8 may be maintained at 10 kv. (or in a similar ratio relatively to the other electrodes 5, 6 and 7).

In an electrostatic tube with a flat unipotential cathode in which the electron pencils are brought to a cross over after the cathode, but in which there is no auxiliary focusing means such as is formed by the mesh 2 and electrode 3, electron pencils from the marginal regions of the cathode 1 would cross the axis of the tube nearer the cathode than those from near the axial regions thereof. The focused image would also lie on a surface markedly concave towards the cathode, because of the stronger focusing field traversed by the marginal electron pencils. An electron pencil is the bundle of substantially all the rays from a given point of the cathode. The effect of image curvature is illustrated in FIGURE 3 which shows two electron pencils 20 and 21 coming to a focus on the concave surface 22. The quality of focus of a picture on the flat luminescent screen 8 depends on two factors, namely the curvature of the image surface and the angle of divergence of the pencils from the image surface 22. It can be appreciated from FIGURE 3 that the angle of convergence is small if the pencil is narrow so that the loss of focus on moving from the surface 22 to the screen 8 is small even at the edges of the screen 8. The picture can be improved by reducing the divergence of the pencils near the target, reducing the curvature of the surface 22 or by both these effects, and the auxiliary focusing means formed by the mesh 2 and the electrode 3 produces both these effects. By the "divergence of a pencil" is meant the relative divergence of two rays emitted in opposite directions tangential to the surface of the photocathode with the most probable energy of emission and is to be distinguished from the divergence of the principal rays of different pencils, which is related to the angle which the principal ray of any particular pencil makes with the axis of the device.

The reduction in the divergence of the pencils is produced by reason of the fact that the mesh 2 is within a certain limiting distance from the cathode, as will be explained subsequently in more detail with reference to FIGURES 4 and 5.

With the arrangement of electrode shown in FIGURE 1, a reduction in curvature of the image surface 22 is achieved by the combined effect on the mesh 2 and the electrode 3, in conjunction with the other electrodes. When said mesh 2 and electrode 3 are included, the field between the cathode 1 and mesh 2 is nearly planar near the axis of the system, but near the electrode 3 it is divergent because of the shape of the equipotential contours and this is as shown by reference 9 in FIGURE 1. Hence the principal rays of the pencils of electrons from the marginal regions of the cathode 1 which are initially normal to the cathode surface, diverge from the axis on traversing the curved field due to the mesh 2 and the electrode 3 and after emerging from the mesh 2 converge toward and cross the axis of the tube on traversing a convergent field due to the converging electrostatic lens formed by the electrodes 4 to 7. On the other hand, pencils leaving the cathode 1 nearer to the axis of the device, traverse the field due to the mesh 2 and the electrode 3 in a region of lesser curvature, and so the principal rays are caused to diverge from the axis to a lesser extent,

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if at all, before the pencil emerges from the mesh 2. Therefore pencils from the marginal regions cross the axis relatively further from the cathode 1 than would be the case in the absence of the mesh 2 and electrode 3, and hence relatively closer to the point where the axial pencils of electrons cross the axis. This extra divergence of the principal rays of the marginal pencils relative to the axis is also associated with the extra divergence of the marginal pencils themselves so that they come to a focus nearer the target than would otherwise be the case and the curvature of the image surface is reduced. The electrode 3 may be cylindrical or conical or otherwise suitably shaped. However the electron pencils may not all, in practice, cross over the axis at the same point as indicated.

If desired the electrode 4 may be replaced by a plurality of shorter electrodes spaced along the tube. Moreover, the potentials of the various electrodes may be varied according to particular requirements regarding magnification and picture quality.

The tube shown in FIGURE 2 embodies an electrode arrangement similar to that shown in FIGURE 1, the electrode 4 being in the form of five short electrodes all maintained at the same low potential. The electrodes are contained as shown in a substantially cylindrical envelope 10 having one end re-entrant and accommodating a support for the photo-electron emissive cathode 1. The mesh 2 is mounted in an annular support 11 which is integral with the electrode 3 and the electrodes 4 to 7 are painted on areas between grooves 12 provided around the envelope 10. Contact buttons for connection to the electrodes 4, 5, 6 and 7 are indicated by dotted circles 10a. The envelope 10 is provided with side arms 13 for the introduction of evaporators for forming the photo-electron emissive cathode 1. The luminescent screen 8 is formed on a support 14 which is sealed as indicated at the other end of the envelope 10 to the cathode 1.

In the modification of the invention shown in FIGURE 5, the sleeve electrode 3 is not provided and the auxiliary focusing means comprises the mesh 2 alone. The tube is otherwise similar to that illustrated in FIGURES 1 and 2 and corresponding parts are denoted by the same references. The mesh is however much closer to the cathode 1 than in the case of FIGURES 1 and 2, this being possible in the absence of the sleeve electrode 3. Therefore although substantially no reduction of the curvature of the surface 22 can be achieved as by the interaction, as described, of the mesh 2 and the electrode 3, the pencils are narrower by reason of the closer spacing of the mesh assuming the voltage of the mesh is the same as in FIGURE 1.

It can be shown that the angle of divergence of a pencil from the surface 22 of FIGURE 3 is small if the width w of the pencil is small at the equivalent thin lens which produces focusing between the mesh and the target of the pencil at the surface 22. It can further be shown that this width w is small if V , the voltage difference between the mesh 2 and the surface 1, is large and if the distance of the equivalent thin lens from the surface 1 is small. Thus it is desirable to maintain S , which is the distance of the mesh 2 from the surface 1, as small as possible, if a reduction of the angle of divergence of the pencils from the surface 22 is the only criterion, but in practice S must be sufficient to avoid breakdown between the mesh 2 and the surface 1.

The shadow ratio of the mesh 2 according to the invention must be small to reduce the cathode current intercepted by the mesh to a reasonably low value. The shadow ratio is usually expressed as a percentage and is the percentage of the overall area of the mesh which is impervious to electrons. In practice the shadow ratio should be less than 55%, say 30%. Also the aperture size should be small to reduce aberrations.

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Therefore, the mesh 2 should be a fine pitch mesh of low shadow ratio. By way of example the mesh 2 may have a pitch of from 500-1500 filaments per inch for a cathode 1 of 1 to 2 inches diameter. In an arrangement such as illustrated in FIGURES 1 and 2 the distance S is chosen with a view not only to reducing the divergence of the pencils but with a view to reducing the curvature of the image surface 22 and in this form of the invention the distance S may be between 0.05 and 0.5 of the effective width of the cathode surface. In the particular form of the invention shown in FIGURE 1 or 2, the spacing S is 0.4 of the diameter of the cathode. On the other hand in the case of an arrangement such as illustrated in FIGURE 5, in which S may be chosen solely with a view to reducing the divergence of the pencils, S may be smaller.

It will be understood that the mesh 2 in the examples illustrated has mutually perpendicular filaments, and the above relationships with regard to one particular number of filaments applies to both sets. In the embodiments which are illustrated, the mesh 2 has 500 filaments per inch and the cathode diameter is 1.8 inches. The value of the potential V applied to the mesh 3 may depend upon the value of S , since it can be increased as S increases.

Although the invention has been particularly described with reference to its application to an electron discharge tube embodying a photo-electron emissive cathode it may be applied to other devices in which electrostatic focusing of electrons from an electron emissive surface to a target is employed. Other modifications may also be made. For example where the electrode 3 is provided, it may be separated from the mesh 2 and maintained at a different potential therefrom.

With a close spaced mesh, such as represented in FIGURE 5, the mesh should be sufficiently taut to avoid any substantial displacement of the centre of mesh due to electrostatic attraction of the mesh towards the photo cathode 1.

It will be appreciated that the paths of the principal rays shown in FIGURES 1 and 5 are idealised, and such rays would not cross the axis at a single point.

What I claim is:

1. An electron discharge tube comprising
 - (a) an evacuated envelope,
 - (b) a substantially flat image electron-emissive surface,
 - (c) a substantially flat target for electrons emitted from said emissive surface, said surface and target between spaced one from the other,
 - (d) a converging electrostatic focusing means for focusing pencils of electrons emitted from said surface to form an inverted image on said target, said focusing means comprising a plurality of annular electrodes around the electron optical path from said emissive surface to said target,
 - (e) and auxiliary focusing means including a mesh parallel to said emissive surface, said mesh having at least 500 filaments in a distance equal to the diameter or larger dimension of said emissive surface,
 - (f) said mesh being spaced from said emissive surface by a distance not exceeding one half said diameter or larger dimension.
2. An electron discharge tube comprising
 - (a) an evacuated envelope,
 - (b) a substantially flat image electron-emissive surface,
 - (c) a substantially flat target for electrons emitted from said emissive surface, said surface and target between spaced one from the other,
 - (d) a converging electrostatic focusing means for focusing pencils of electrons emitted from said surface to form an inverted image on said target, said focusing means comprising a plurality of annular

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- electrodes around the electron optical path from said emissive surface to said target,
- (e) and auxiliary focusing means including a mesh parallel to said emissive surface and an annular conductive member around the electron optical path from said surface to said mesh, 5
- (f) said auxiliary focusing means causing the angle with respect to the axis of the device of the principal rays of the electron pencils from said emissive surface to vary with distance from the axis of the tube so as to reduce curvature of the image field. 10
3. An electron discharge device comprising
- (a) an evacuated envelope,
- (b) a substantially flat image electron-emissive surface, 15
- (c) a substantially flat target for electrons emitted from said emissive surface, said surface and target between spaced one from the other,
- (d) a converging electrostatic focusing means for focusing pencils of electrons emitted from said surface to form an inverted image on said target, said focusing means comprising a plurality of annular electrodes around the electron optical path from said emissive surface to said target, 20
- (e) and auxiliary focusing means consisting of a mesh of greater extent than said emissive surface, parallel to said surface, and spaced from said surface by a distance less than half the diameter or larger dimension of said surface, 25
- (f) and means maintaining said mesh at a positive potential relative to said emissive surface close to but below the breakdown potential. 30
4. An electron discharge tube comprising
- (a) an evacuated envelope,

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- (b) a substantially flat image electron-emissive surface,
- (c) a substantially flat target for electrons emitted from said emissive surface, said surface and target between spaced one from the other,
- (d) a converging electrostatic focusing means for focusing pencils of electrons emitted from said surface to form an inverted image on said target, said focusing means comprising a plurality of annular electrodes around the electron optical path from said emissive surface to said target,
- (e) and auxiliary focusing means including a mesh parallel to said emissive surface and an annular conductive member around the electron optical path from said surface to said mesh, said conductive member being conductively connected to said mesh and projecting from it toward said electron emissive surface,
- (f) said auxiliary focusing means causing the principal rays of the electron pencils from marginal regions of said emissive surface to diverge from the axis initially before being caused to converge towards the axis by said converging focusing means, so as to reduce curvature of the image field.

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