Dec. 15, 1959 R. W. HUNTER 2,917,658

ELECTRON DISCHARGE DEVICES

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FIG. 1

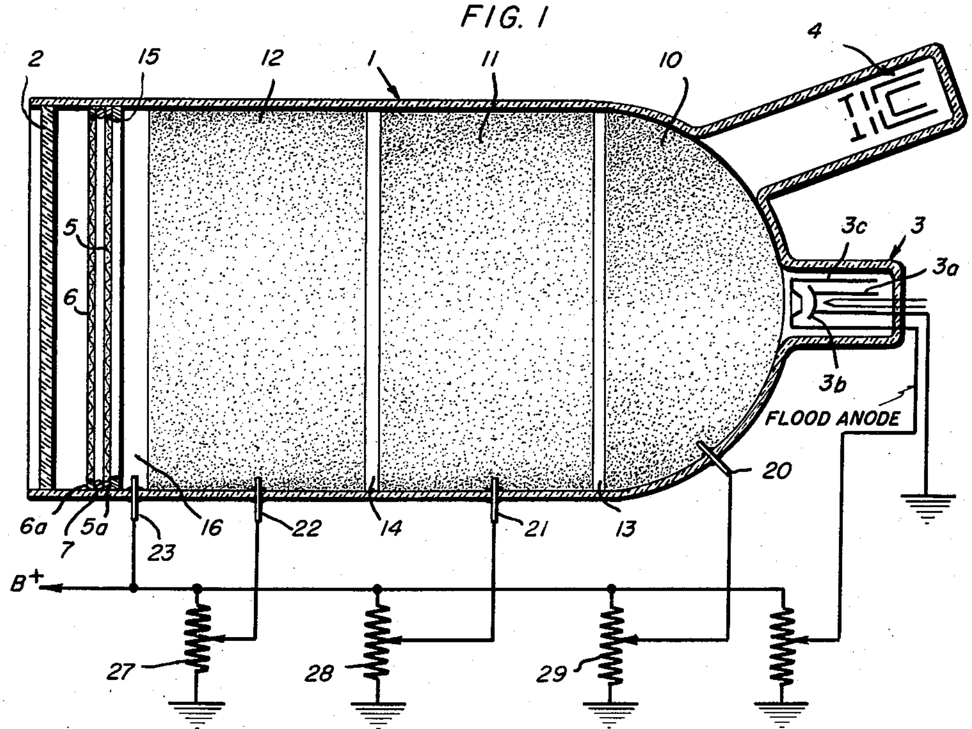
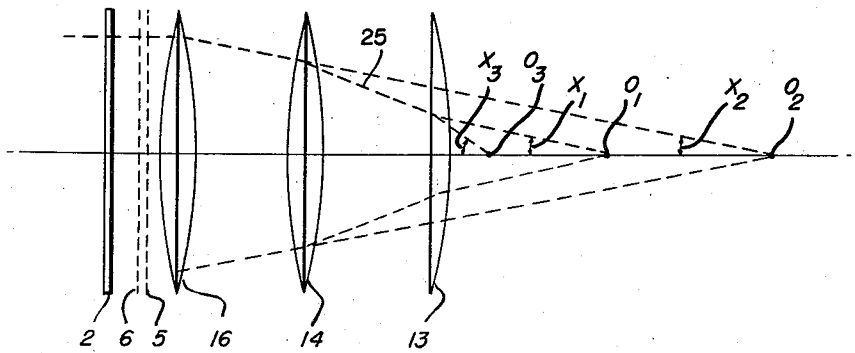


FIG. 2



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ELECTRON DISCHARGE DEVICES

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This invention relates to electron discharge devices and is particularly directed to devices with an extended target area and an electron gun for uniformly bombarding or "flooding" the area.

In a number of display tubes, the electron image of a video signal is "written" on a planar storage target screen electrode and the image is then transferred to a closely spaced phosphor anode by a low density flood beam of electrons. For a shadow-free visual image, it is necessary that the flood beam impinge upon the screen normal to the plane of the screen and that the density of electrons be uniform throughout the target screen area.

For practical reasons, the cathode for supplying the flood beam is small in size compared to the screen area to be served. In fact, in some tubes the electron source may be considered a point source of electrons. For reasonable screen-to-cathode spacing within an evacuated envelope, the solid angle at the cathode subtended by the screen is necessarily quite wide. A wide solid angle, in turn, leads to a serious problem of spherical aberration. Shading or uneven illumination of the phosphor anode clearly indicates the spherical aberration and non-uniform angles of approach of the electrons at the surface of the storage target screen. Angles less than ninety degrees (90°) occur first at the periphery of the screen when the gun is spaced along a line perpendicular to the center of the screen. Attempts heretofore to collimate the flood beam has left much to be desired.

The object of this invention is an improved display tube with means for providing a flood beam which is uniform in density and is well collimated throughout the planar area to be flooded.

The objects of this invention are attained in a display tube having a planar target screen electrode, a writing gun for scanning and writing an electron image on the planar electrode and a flood gun spaced from the center of the electrode on a line substantially perpendicular to the center of the electrode for flooding the planar electrode with electrons, characterized in that a negative electron lens concentric with said line is disposed adjacent said flood gun for diverging the beam of the gun, and a double positive electron lens concentric with said line is disposed between the negative lens and said planar electrode for converging the electrons to paths normal to the electrode.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a longitudinal sectional view of one tube embodying this invention; and

Fig. 2 is a diagram of the lens system of the tube of Fig. 1 in analogy to geometric optics.

The particular electron discharge device chosen for

illustrating this invention is of the "Iatron" type comprising the tubular envelope 1 with the planar phosphor anode 2 across one end of the envelope and the flood gun structure 3 at the other end. The writing gun 4 is eccentrically disposed at the flood gun-end of the tube. In the Iatron, the collector screen 5 and the storage target screen 6 are placed immediately in front of the phosphor anode. An electron charge image is written upon the storage target 6 by the writing gun 4. This charge image in turn modulates the low velocity electron flow from the flood gun 3, in proportion to the local target charge density at any particular point on the storage surface, thus controlling the position and current density of flood electrons reaching the phosphor screen. The requirement that the flood electrons approach the collector screen and storage target normal to their plane gives rise to the invention. This gun operates at zero (0) voltage on cathode acceleration of the beam to the electrodes primarily accomplished by the collector screen. According to this invention, three focusing electrodes 10, 11 and 12 are disposed concentric with the envelope between the gun and the planar electrodes. The potentials of these three electrodes are positive with respect to the cathode but the potential of the center electrode 11 is lower than the potentials of electrodes 10 and 12 so that in the plane 13 between the first two electrodes is produced a negative electrostatic lens. The relative potentials between electrodes 10 and 11 are so chosen that the gun beam is sufficiently diverged. With this selection of potentials, accordingly, the electron lens at plane 14 is positive and conveges the electron beam. A second positive electron lens is between electrode 12 and the collector screen 5. This second positive lens is in the plane 16. By first initially diverging the beam at lens 13 to a diameter sufficient for obtaining a maximum display size, the positive lens at 14 still has low abberation, because the beam diameter at that lens is small as compared to the lens itself. The positive lens at 16 has low aberration, because its effective object distance is at O_2, thus reducing the angle to X_2. The relative potentials of 10, 11 and 12 are easily adjusted so that the electrons are collimated and approach the planar electrodes 5 and 6 substantially normal to the plane of the electrodes.

More specifically, the tube embodying this invention shown in Fig. 1 comprises the tubular glass envelope 1. The glass plate 2 sealed in one end of the envelope is preferably of optical glass and is internally coated with a transparent film of electroluminescent film such as zinc cadmium sulphide, which luminesces when bombarded with electrons. Closely spaced in front of the phosphor anode is the storage target screen 6 with an electron transmissivity of, say, 30% to 50%, and with a layer of semi-conducting material such as silicon monoxide, coated on the gun side of the screen. In front of the storage target 6 is placed the collector screen 5 of sufficient transmissivity as to not impair the resolution and yet collect secondary electrons from the storage target. Conventionally, the collector seal ring 15, collector screen 5, and the collector mounting ring carried by the envelope are operated at the highest positive potential within the lens system, for accelerating and focusing purposes. Conventionally, the two planar electrodes 5 and 6 are supported on rings 5a and 6a, respectively, fitted into the envelope and are mounted apart by the ceramic insulating spacer 7. These screens are in turn mounted rigidly to the tube by metal tabs welded between the ring 5a and the ring 15, which is thermally sealed to the glass.

At the opposite end of the envelope, the writing gun 4 is mounted with beam accelerating and focusing electrodes and with scanning deflection coils or plates not shown, for writing an electron image on the storage target 6. Dynamic focusing is, of course, required to correct for the keystone distortion to be expected from the eccentric writing gun.

The flood gun 3 is of the "modified Pierce" type comprising the cathode sleeve *3a* with the dish-shaped coated cathode surface *3b* disposed opposite the conical opening of the gun anodes *3c*. The optics of the gun anode and cathode are such that a substantially rectilinear flow of electrons issue from the gun opening.

According to this invention, the electrons, after leaving the gun, are subjected to a negative field produced by concentric electrode **10**. The angle of divergence can be made sufficiently wide so that the electrons passing through plane **13** are further diverged and are substantially evenly distributed, and yet the divergence is not so great that the beam diameter equals the diameter of the lens thereby avoiding aberration. The angle of divergence is quite sensitive to the axial placement of the gun opening with respect to the neck of the envelope at the gun. That is, the proximity of the electrode **10** to the beam as it emerges from the gun is most sensitive to that portion of the electrode which is closest to the gun.

Electrodes **11** and **12** are concentric with the envelope and are insulatingly spaced between electrode **10** and collector seal ring **15**. In the embodiment illustrated, the electrodes **10**, **11** and **12** are shown as carbon or "aquadag" coatings on the inner surface of the glass envelope. Metal cylindrical electrodes insulatingly spaced in the envelope would be the full electrostatic equivalent. Where the electrodes are carbon coatings as shown, lead-in conductors **20**, **21** and **22** are conveniently sealed through the side of the envelope and the inner ends thereof sprayed with the carbon coating material to make good electrical contact with the lead-ins. Lead-in **23** is connected to the screen mounting **15**.

According to an important feature of this invention, electrodes **10** and **12** are at about the same voltage, while the potential of electrode **11** is at a voltage below either **10** or **12**. While moving from a positive field to a field that is relatively negative, or less positive, across plane **13**, the electrons enter a decelerating region and are diverged. While moving across plane **14**, however, the electrons enter a relatively more positive field and are converged. Referring to Fig. 2, if the actual cathode is at point O_1, and the normal beam angle is x_1, the lens **13** will increase the apparent beam angle represented by lines **25**. Electrons at the periphery of lens **14** will be seen and will be refracted as though the cathode were at point O_3, with the increased beam angle x_3. This will increase spherical aberration if the beam diameter at **14** is large, nearing that of the lens. However, if the beam diameter is small, not too much aberration will result at lens **14**. Further convergence by lens **16** will fully collimate the beam without aberration due to its effectively long object distance O_2. The total aberration of a multiple-lens system is small if the sum of the aberrations from each lens is less than that produced by a simple lens.

One voltage supply for energizing the focusing electrode is shown in Fig. 1. The potentiometers are tapped as shown with ring **15** and the collector **5** connected to the highest positive potential. Potentiometer **27** is preferably set to make electrode **12** stand at about one-half the voltage of the ring **15**, while electrode **10** is adjusted by means of potentiometer **29** to operate at about one-quarter the ring **15** voltage. Electrode **11** is adjusted by means of potentiometer **28** for minimum shading at the phosphor, which is at some voltage below the voltage of electrode **10**. If, for example, the envelope diameter is about five (5) inches and the axial lengths of electrodes **10**, **11** and **12** are, respectively, two (2) inches, one and five-eighths (1⅝) inches and two (2) inches, the ring **15** and collector screen **5** should be operated in the 100 to 250 volt range. When ring **15** was 200 volts, good results were obtained by operating electrode **12** at 100 volts, **10** at 30 volts and **11** at 20 volts. A wide variety of voltage combinations can be found for producing satisfactory results.

While the principles of the invention have been described in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of the invention.

What is claimed is:

1. In a storage tube, a planar electrode, an electron gun for providing a low velocity flood beam of electrons, said gun being spaced from the planar electrode on a perpendicular line to the electrode, and a lens system between said gun and said electrode for uniformly flooding the electrode with collimated electrons from said gun including successively a first lens for diverging the electrons, a second lens for converging the electrons, and a third lens for converging the electrons.

2. In a storage tube, a tubular envelope, a planar target electrode across one end of the envelope, an electron gun at the other end of the envelope for directing a low velocity flood beam of electrons toward said target electrode; three end-to-end tubular electrodes concentric with the envelope between the gun and planar electrodes, separate lead-in conductors for each of said tubular electrodes and said target electrode, a source of operating potential connected to each of said lead-in conductors, the source connected to the lead-in conductor of the center tubular electrode being at a potential below the potential of the sources connected to the lead-ins of the other tubular electrodes so that the electrostatic fields at opposite ends of the center electrode respectively diverge and converge the electron beam moving from the gun toward the target electrode, the source connected to the lead-in of the tubular electrode adjacent said target electrode being at a potential below the potential of the source connected to the lead-in of said target electrode so that the electrostatic field between said target electrode and said adjacent tubular electrode further converges the electron beam moving from the gun toward said target electrode.

3. In combination in a flood gun-type tube, a planar target electrode, an electron gun spaced from and facing the target electrode for directing a low velocity flood beam of electrons toward said target electrode, a negative electron lens and a double positive electron lens sequentially disposed between the gun and planar electrode.

4. In combination in a flood gun-type tube, a target of extended surface area, an electron gun of the "Pierce" type spaced from and facing the target for projecting a collimated beam of low velocity flood electrons toward said target, means for spreading the beam to uniformly flood said extended area comprising first a diverging electrostatic lens in front of the gun, and next a double converging electrostatic lens downstream from the diverging lens.

5. In combination in a storage tube, a tubular glass envelope, a flattened target electrode across one end of the envelope, an electron flood gun at the other end of said envelope, a collector electrode between said flood gun and said target electrode and adjacent the latter, a coating of conductive material on the inner wall of said envelope substantially covering said envelope between said gun and said collector electrode, said coating being circumferentially divided into three mutually insulated tubular sections, separate lead-ins for each of said sections and said collector electrode; a voltage source connected to each of said lead-ins, the voltage source connected to the lead-in of the intermediate one of said coating sections being at a voltage below the voltages of the

voltage sources connected to the lead-ins of the coating sections upstream and downstream from said intermediate coating section, the voltage source connected to the lead-in of said collector electrode being at a voltage higher than the voltage source connected to the lead-in of the coating section adjacent said collector electrode, said adjacent coating section terminating short of said collector electrode.

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