March 30, 1943.   D. W. EPSTEIN   2,315,367

CATHODE RAY TUBE

Filed July 31, 1940

FIG. 1.

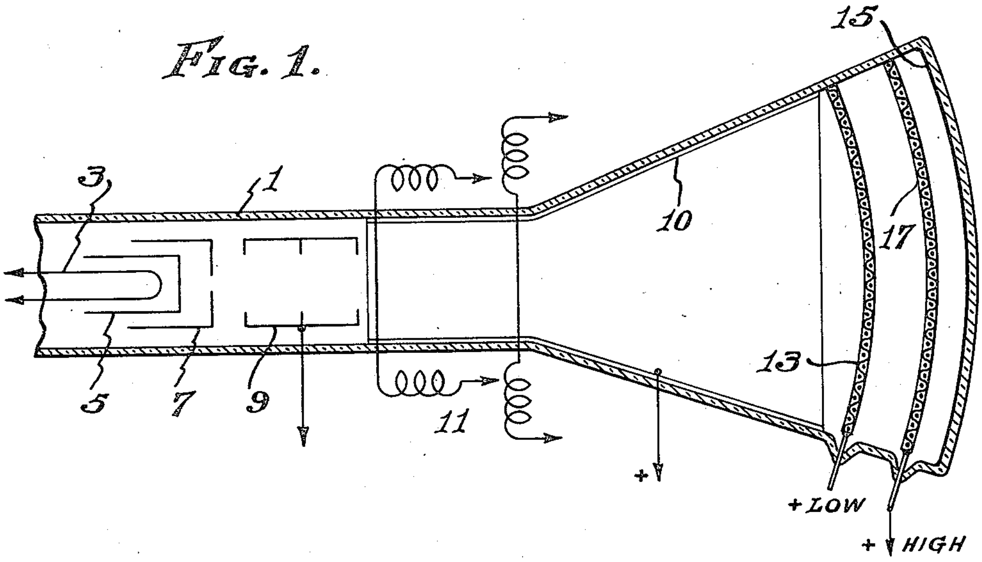


FIG. 2.

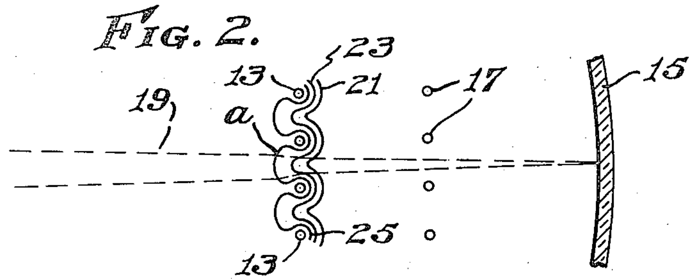


FIG. 3.

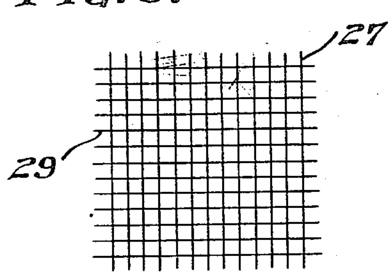
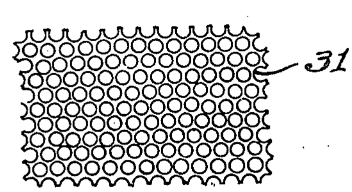


FIG. 4.



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UNITED STATES PATENT OFFICE

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CATHODE-RAY TUBE

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6 Claims. (Cl. 250—27)

This invention relates to cathode ray tubes and more particularly to tubes capable of producing a brilliant image and adapted to be used for the projection of an optical image on a large screen.

In order to obtain a brilliant image from a cathode ray tube, it is necessary to generate an electron beam whose electrons travel at a very high velocity, so that, when the electrons impinge on the luminescent surface or image screen, there results a brilliant point of light. However, it has been found that, the greater the velocity of the electrons in the electron beam, the more difficult it is to satisfactorily deflect the beam in order to produce the desired image. Several different methods and means have been proposed in which the cathode ray beam is deflected before the electrons composing the beam have been accelerated.

It has been proposed to provide a cathode ray tube having one or more accelerating rings located along the length of the tube following the deflecting means in the direction of the luminescent screen. It is true that this method increases the velocity of the electron beam after it has been deflected but it has been accompanied by the objectionable feature that the change in velocity of the electrons by a single or a series of accelerating electrodes, after they have been deflected, causes a serious defocusing of the electron beam so that the beam spreads before intercepting the luminescent screen causing a loss of detail in optical image. This also results in a considerably lower increase in deflection sensitivity because the higher voltage field penetrates the region of the deflecting field.

It has also been proposed to place a screen at a position intermediate the deflection means and the luminescent screen and maintain this screen at a relatively low positive potential. A high potential accelerating anode is then placed at the end of the tube adjacent the luminescent screen. Although the above mentioned method enables the electron beam to be deflected while at low velocity it is incapable of producing a sufficiently fine spot because of the lack of correct focusing.

According to this invention, the cathode ray beam is deflected in a region of low potential and is accelerated and furthermore focused after deflection. This is accomplished by providing a large number of separate lenses closely adjacent to each other in a plane substantially perpendicular to the electron beam so that there is at least one different lens for each position of the cathode ray beam. Such an array of electron lenses may be obtained by placing in front of the luminescent screen two or more meshes or perforated sheets so aligned that the openings of one sheet are lined up or are coaxial with the openings of the other sheet or sheets. A high potential difference is then applied between these sheets to accelerate the electron beam.

Accordingly, the principal object of this invention is to provide a cathode ray tube capable of producing a highly brilliant image.

A further object of this invention is to provide a cathode ray tube in which the electron beam is deflected while its electrons are traveling at a low velocity, accelerating and further defocusing the beam after deflection.

Other and incidental objects of the invention will be apparent to those skilled in the art from a consideration of the following specification in connection with the accompanying drawing, in which:

Figure 1 shows a cross-sectional view of the proposed cathode ray tube,

Figure 2 shows an enlarged portion of the electron lenses to illustrate its function, and

Figures 3 and 4 show an enlarged portion of two possible forms of electrodes suitable for use as multiple electron lenses.

Referring now to Fig. 1, a cathode ray tube is provided with an evacuated envelope 1, a heater element 3, and a cathode 5 adapted to produce electrons which are controlled by a control electrode 7 and accelerated by first anode 9 and focused by the field formed between the first anode 9 and the second anode 10. The electron beam thus produced is deflected by deflecting coils 11 or any other well known deflecting means. The first in a series of perforated meshes or perforated sheets 13 is positioned substantially parallel to the luminescent screen 15 and is maintained at a positive potential substantially equal to that of the second anode 10. A second mesh or perforated sheet 17 having its perforations lined up or coaxial with the perforations of mesh 13 is also positioned between the mesh 13 and the luminescent screen 15 and is supplied with a higher positive potential than that of screen 13 and second anode 10 in order to produce a large acceleration of the electrons in the electron beam. Leads marked +high and +low may be connected to any suitable source of potential.

The distance between the meshes 13 and 17 is dictated by considerations of voltage breakdown and focusing efficiencies.

Referring now to Fig. 2, wherein like numerals refer to similar parts, 13 is the low potential mesh closest the electron gun, 15 is the luminescent screen, and 17 the high potential mesh. The electron beam is represented by the area included by the broken line 19. Surfaces of equipotential are represented by lines 21, 23 and 25 which emerge through the holes in the mesh screen 13 to produce a profound effect on the electron beam and cause it to converge so that, by the time the electrons reach the luminescent screen 15, the electron beam has a smaller diameter than it had at the position of the first mesh 13.

It is very convenient to treat the focusing action of each of the holes in the mesh or disc in terms of geometric electron optics. In geometric electron optics, use is made of the well-known fact that the trajectory of an electron in electrostatic fields is similar to the trajectory of a ray of light in refractive media. Because of this similarity, the concepts of geometric optics such as lens, focal length, etc., may be transferred to electrostatic fields. From this point of view, a cathode ray tube may be regarded as an axially symmetric optical system. The electrostatic focusing system may be considered as an electrostatic lens. It has been found that the index of refraction at any point of an electrostatic field is proportional to the speed of the electron at the point and, keeping in mind that the speed of the electron is proportional to the square root of its potential, and, since the potential in the area 21, 23 and 25 is a continuous scalar function of position, it follows that the index of refraction of an electrostatic field is a continuous function of position. Optically speaking, this means that an electrostatic field constitutes an isotropic, nonhomogeneous medium for electrons (corresponding to a medium of uniform variable density for light rays).

Therefore, certain forms of electrostatic fields will act as focusing systems or "lenses" for electron beams, just as certain forms of refracting media act as focusing systems for light beams.

Returning now to Fig. 2, it follows that each equipotential surface 21, 23 and 25 represents a surface of constant index of refraction. In Fig. 2, there are shown only a few of the equipotential surfaces. Actually there are, of course, an infinite series of equipotential surfaces.

To illustrate the focusing action of the electrostatic field, consider an electron of the beam 19 intercepting the equipotential surface 25 at point *a*. The electron beam will be attracted in a direction perpendicular to the equipotential surface 25. The amount of attraction will, of course, be proportional to the magnitude of the potential gradient at the point *a*. This changes the direction of the electron beam so that it arrives at the image screen nearer the center of the beam 19. This electron beam focusing phenomenon is further explained by D. W. Epstein in an article entitled "Electron optical system of two cylinders as applied to cathode-ray tubes," I. R. E., vol. 24, number 8, page 1095, August 1936.

It is thus seen that an electrostatic field having axial symmetry will bring a paraxial electron beam to a focus. Fields possessing axial symmetry may be produced by applying various voltages to electrodes having geometric axial symmetry, such as coaxial cylinders, and, furthermore, a large number of individual fields possessing axial symmetry may be produced by applying various voltages to two or more perforated sheets so aligned that the openings of one sheet are lined up or coaxial with the openings of the other sheet.

In the case of a mesh electrode a focusing field is produced which although not possessing full axial symmetry, produces an electric field capable of focusing the beam to a small spot.

Figure 3 represents an enlarged portion of a mesh composed of vertical conducting wires 27 and horizontal conducting wires 29. The gauge of this mesh is so chosen that the openings occur frequently enough that there is no falling off of detail of the projected image. For example, if this tube is used with television apparatus each picture element would correspond to one or more openings in the mesh.

Figure 4 illustrates the use of a perforated sheet in which the holes 31 all have a substantially uniform diameter and are closely spaced so as to provide an optical image of very high detail.

While a number of systems for carrying this invention into effect have been indicated and described it will be apparent to one skilled in the art that this invention is by no means limited to the particular organizations shown and described but that many modifications may be made without departing from the scope of this invention as set forth in the appended claims.

I claim as my invention:

1. A cathode ray tube having an electron gun, a luminescent screen, electron beam deflecting means, and a plurality of electrodes mounted adjacent said screen and each provided with a plurality of openings so aligned that the openings of one electrode are substantially in line with the openings of adjacent electrodes.

2. A cathode ray tube having an electron gun, a fluorescent screen, electron beam deflecting means and a plurality of electrodes adjacent said screen comprising wire meshes so aligned that the openings of one electrode are substantially in line with the openings of adjacent electrodes.

3. A cathode ray tube having an electron gun, a luminescent screen, electron beam deflecting means and two focusing opaque electrodes adjacent and substantially parallel to said screen, each of said anodes comprising a perforated sheet so aligned that the openings of one sheet are in line with the openings of adjacent sheets.

4. A cathode ray tube having an electron gun, a luminescent screen, electron beam deflecting means, and two focusing electrodes adjacent and substantially parallel to said screen, each of said electrodes provided with a plurality of openings so aligned that the openings of one sheet are in line with the openings of adjacent sheets, and a source of substantially constant positive potential connected to said electrode adjacent said screen of sufficient magnitude to accelerate substantially all the electrons through the focusing electrode closest said gun.

5. A cathode ray tube having an electron gun, a luminescent screen, an anode, electron beam deflecting means, and a plurality of focusing electrodes adjacent and substantially parallel to each other and said screen, each of said electrodes comprising a perforated sheet so aligned that the openings of each sheet are in line with the openings of adjacent sheets of sufficient mass to prevent luminescence due to electronic bombardment of the electrons from said gun and a source of relatively high and constant positive potential adapted to supply said focusing electrode nearest said screen with a higher potential than is sup-

plied to any of the other of said elements of the cathode ray tube.

6. A cathode ray tube of the high vacuum type comprising in combination an envelope containing electron means including a cathode and a first anode for developing a cathode ray beam, a fluorescent screen in the path of said ray and a plurality of conductive, opaque and open work electrodes adjacent and substantially parallel to said screen, means for maintaining the electrode nearest said beam developing means at a substantially uniform positive potential with respect to said first anode, and means for maintaining another of said electrodes at a relatively uniform potential more positive than the potential of the other of the said electrodes nearest said beam developing means.

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