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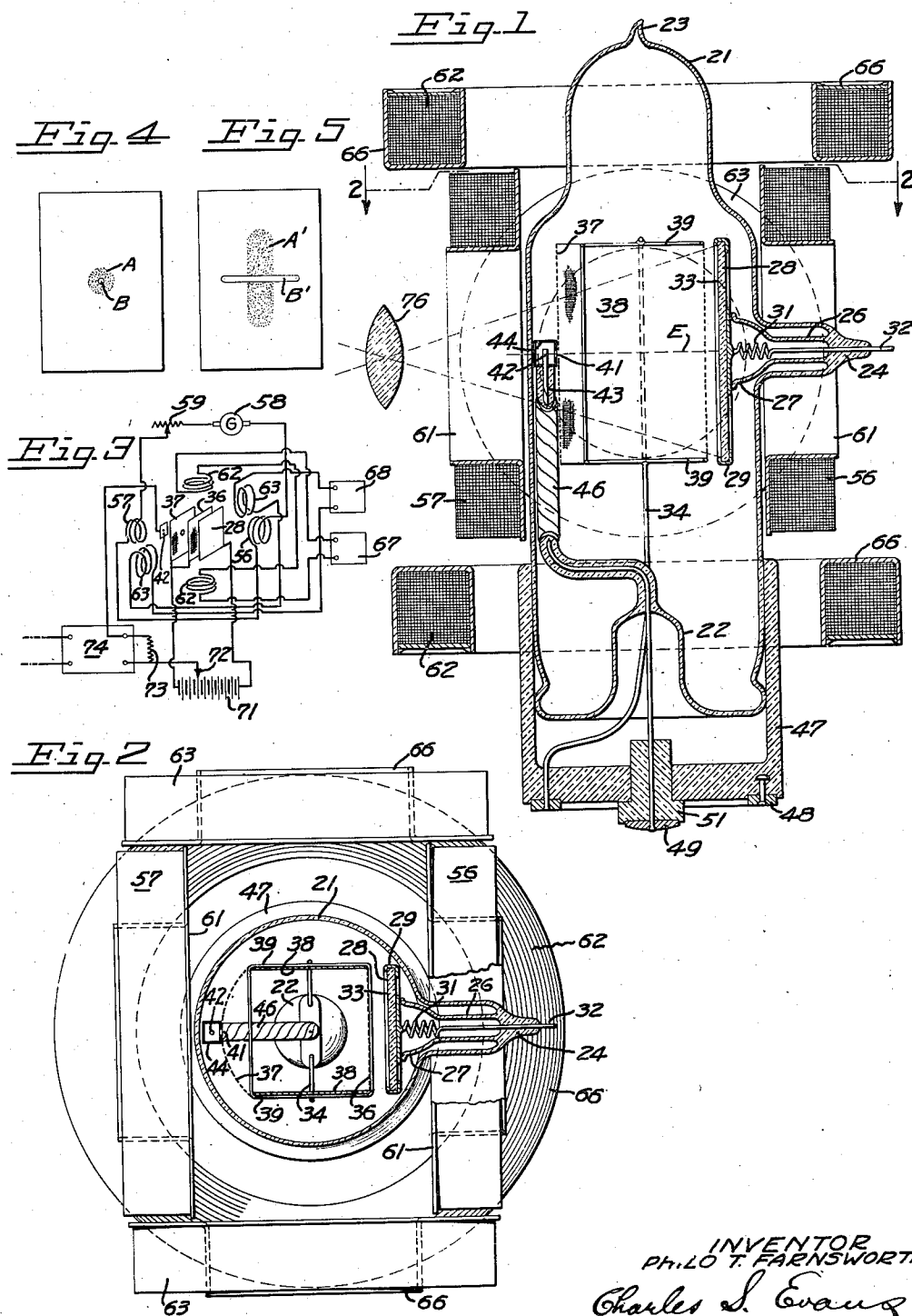
P. T. FARNSWORTH

1,986,330

ELECTRICAL DISCHARGE APPARATUS

Filed April 17, 1928

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 6

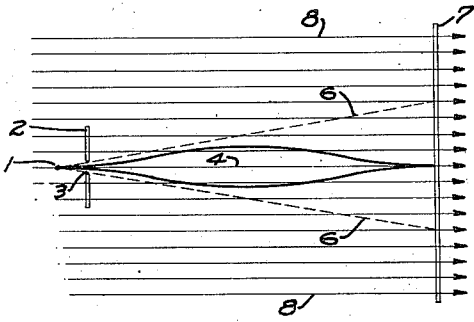


Fig. 11

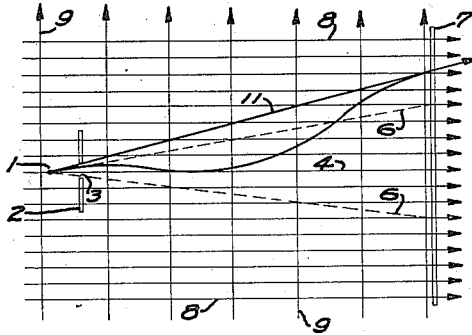


Fig. 7

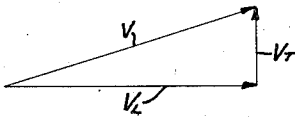


Fig. 8

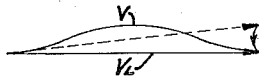


Fig. 9

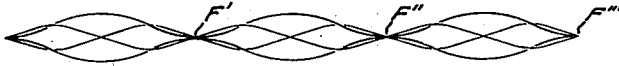


Fig. 10



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UNITED STATES PATENT OFFICE

1,986,330

ELECTRICAL DISCHARGE APPARATUS

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mesne assignments, to Television Laboratories,
Inc., San Francisco, Calif., a corporation of
California

Application April 17, 1928, Serial No. 270,673

13 Claims. (Cl. 250—27.5)

My invention relates to electric ray devices in which it is desirable that the rays be parallel, and has particular reference to cathode ray oscillographs, television apparatus, and the like.

5 An object of my invention is to provide a cathode ray apparatus in which the trace of the ray upon its target is of substantially the same size and shape as the area from which the ray is emitted.

10 Another object of my invention is to provide a tube for generating a sharply focused beam of cathode rays, without the use of an ionized gas within the tube.

15 A further object of my invention is to provide a cathode ray apparatus for use in television which will give maximum definition in the transmitted picture.

My invention has other objects and valuable features, some of which will be set forth in the following description of my invention which is illustrated in the drawings forming part of the specification. It is to be understood that I do not limit myself to the showing made by the said description and drawings, as I may adopt varying forms of my invention within the scope of the claims.

Referring to the drawings:—

Figure 1 is a vertical sectional view of a television transmitting apparatus embodying my invention.

Figure 2 is a transverse sectional view of the apparatus of Figure 1, the plane of section being indicated by the line 2—2 of Figure 1.

Figure 3 is a schematic diagram of the transmitting tube and auxiliary apparatus.

Figures 4 and 5 are views of the sensitive screen of a cathode ray device, showing the trace of the rays under different operating conditions.

Figures 6 to 11 inclusive are diagrams illustrating electron paths under varying conditions. Figure 6 shows a pencil of cathode rays with and without a longitudinal magnetic field acting upon them. Figure 7 is a vector diagram of the velocity of an outer ray in the pencil; Figure 8 shows the effect of the magnetic field on the ray of Figure 7; Figure 9 shows the recurring focal points in a pencil of rays in the magnetic field, the paths of four rays in the circumference of the pencil being shown; Figure 10 shows the effect of increasing the strength of the magnetic field, and Figure 11 shows the effect of a transverse magnetic field superposed on the rays of Figure 6.

Considered broadly my invention comprises a method and apparatus for focusing an electrical

discharge, such as a cathode ray, into a sharp image of the area from which the ray originates; and involves the use of a constant magnetic field longitudinal to the path of the discharge.

If an electrical discharge tube, as for example, a Braun cathode ray oscillograph or a television transmitter tube, such as that described in my co-pending application, Serial No. 245,334, filed January 9, 1928, be provided with a means for establishing a magnetic field longitudinal to the electrical axis of the tube, its ordinary operation is sharply modified.

When such a tube is excited without the use of the longitudinal magnetic field, electrons are emitted from the cathode with small random velocities. These electrons are accelerated by the electrostatic field and each emitting point on the cathode becomes the source of a divergent pencil of cathode rays. If the tube be of the Braun type, the trace of the pencil upon the fluorescent screen is visible as a somewhat diffuse spot as at A in Figure 4. When an alternating magnetic field is established transverse to the electrical axis the spot is deflected in a plane normal to the magnetic field and becomes visible as a blurred line as shown at A' in Figure 5.

If we now establish a longitudinal magnetic field of proper strength two effects ensue. First, the formerly diffuse spot focuses to a sharp image of the emitting portion of the cathode, as is shown at B in Figure 4; and second, the plane of the deflection caused by the alternating transverse magnetic field rotates. Weak longitudinal magnetic fields cause but slight rotation of the plane of deflection but when the magnetic field is strong enough to bring the rays to a sharp focus the rotation becomes 90° i. e., parallel to the deflecting magnetic field instead of perpendicular thereto. This is illustrated at B' in Figure 5.

The reason for these effects may be understood by reference to Figures 6 to 11 inclusive. Consider a cathode comprising a single emitting point 1 and an anode 2 having a small opening 3 on the electrical axis 4. A pencil of cathode rays 6 passes through the opening and is received by a screen 7. A magnetic field parallel to the electrical axis 4 is represented by the lines 8.

Those electrons forming the rays which are traveling exactly parallel to the field, are unaffected by it. The divergent electrons of the pencil have a velocity which may be resolved into a component V_L along the field, and a second component V_T normal to the field. (Figure 7.) The component V_T causes a cutting of the lines of force, with a consequent force exerted on the elec-

tron perpendicular to V_r and to the field. This force deflects the electron into a curved path, but since the magnetic field is uniform the rates at which the lines are cut is not changed by the curvature. The deflection therefore, continues at a constant rate, and V_r , instead of a radial velocity, is transformed to a velocity in a circle whose periphery intersects the line of magnetic force through the point of emission of the individual electron considered. The resultant path of the electron is a helix whose axis is parallel to the magnetic field. (Figure 8.)

This may be expressed mathematically as follows: The electron, having a mass m and a charge e , and moving across the field of strength ϕ with the velocity V_r , is the equivalent of a current $I = eV_r$. This current reacts with the field to produce a force $F = I\phi = eV_r\phi$, acting on the mass m in a direction normal to ϕ and to V_r , and giving it an acceleration

$$\frac{F}{m} = \frac{eV_r\phi}{m}$$

The acceleration being normal to V_r changes it in direction but not in magnitude, and the electron travels in a curved path having a radius

$$r = \frac{mV_r^2}{F}$$

Substituting for F :

$$r = \frac{mV_r^2}{eV_r\phi} = \frac{mV_r}{e\phi}$$

If ϕ is constant, r is also constant, and the path is a circle if V_L be neglected, or a helix if V_L be taken into account.

The angular velocity with which the circular path is traversed is

$$\omega = \frac{V_r}{r}$$

radians per second, or, substituting for r and simplifying,

$$\omega = \frac{e\phi}{m}$$

The electron will therefore describe a complete circle in a time

$$t = \frac{2\pi}{\omega} = \frac{2\pi m}{e\phi}$$

Since V_r does not enter this expression, wherein the only quantity which may be controlled is ϕ , each electron will traverse a complete circle in the small time t , returning to tangency with the line of force in the field through its source. Other tangencies will occur in times $2t$, $3t$, etc.

The component V_L is substantially the same for all of the electrons, and hence tangencies occurring in the same time also occur at the same distance $V_L t$ from the cathode. The point of tangency being the same for all of the electrons having a common point of origin, this point of tangency forms a nodal or focal point for the pencil of rays. V_L may be expressed in volts, and if the distance between the cathode and screen is S , a sharp electrical image of the source will be formed on the screen if

$$S = V_L t = \frac{n2\pi m V_L}{e\phi}$$

or, transposing, where

$$\frac{V_L}{\phi} = \frac{Se}{n2\pi m}$$

when n is any integer. These recurring foci are

shown at F'' , F''' in Figure 9. Increasing the field ϕ tightens the helices and shortens the focal length, as shown in Figure 10.

It will be seen that the axis of the magnetic field need not be within the pencil; if the field be strong enough every electron, no matter how divergent, will eventually return to tangency with a line of force passing through its point of origin. It follows that if the direction of the field be changed the point at which the rays are focused will follow the field.

If, therefore, we superpose a transverse magnetic field, indicated by the lines 9 of Figure 11, on the longitudinal magnetic field, the resultant will be in the direction of the arrow 11, and the focal point of the rays will be deflected to fall upon this line. This explains the change of plane of the deflection caused by the transverse alternating magnetic field as described above.

A gas ion traveling in the path of the ray will not be focused at the same point since its mass is different from that of the electrons. An ionic discharge may be focused, if the field strength is properly adjusted, but in cathode ray apparatus the exhaust is preferably carried as far as possible to eliminate the traces of ionic discharge.

The electrical image formed by focusing in this manner is subject to slight aberrations. These differ from optical aberrations owing to the entirely different mechanism of image formation, but they are of about the same order of magnitude, and the resultant image is as sharply defined as that produced by an ordinarily good lens.

The ability to produce an image of this character is especially valuable in television, and I have therefore, chosen a television transmitter for detailed description as the preferred embodiment of my invention.

The transmitter comprises an evacuated glass vessel 21, provided with a stem 22, evacuating tip 23, and a side seal 24. Within the side seal is an inner stem 26 having a flared inner end 27. A glass plate 28, held by a frame 29, is drawn against the flare by a spring 31 which connects the frame with the cathode lead 32 passing through the seal. The frame connects electrically with a metallic deposit 33 on the inner face of the plate, the deposit being a photo-sensitive material such as potassium hydride, preferably overlying a coating of silver. This deposit is the cathode.

Supported from the stem 22, by the wire supports 34, is the anode structure. At least one of the supports passes through the stem to serve as an anode lead. The anode is prismatic in form. The sides 36 and 37, facing the cathode are of fine mesh wire screen. The remaining sides 38 are metal sheet. Wires 39 at the top and bottom of the structure give rigidity.

Behind a small aperture 41, in the rear screen 37, is a target 42 for receiving and detecting rays from a limited area of the cathode. The target is connected to an insulated lead 43 passing through the stem and is enclosed by a housing 44 which has a single small aperture coinciding with the aperture 41 in the anode screen. The lead is surrounded by an electrostatic shield 46 connected to the housing and the anode.

The tube is provided with a base 47 for connection with a suitable socket. The anode lead 34 connects with a ring 48 on the base, and the target lead 43 terminates in a contact 49, which is provided with additional insulation in the form of a bushing 51 of amber or sulphur.

External to the tube are coils for producing the various magnetic fields. The coils are preferably arranged in pairs with their axes respectively parallel and normal to the electrical axis E of the tube. The diameters and spacing of these coils are preferably so chosen that the fields produced by them are constant over the paths of the rays. The principles of such design are well understood, but owing to space limitations the optimum dimensions have not been shown in the drawings.

The first of these pairs are the concentrating or focusing coils 56 and 57, arranged on either side of the tube co-axially with the electrical axis E. These coils are supplied with direct current as from a generator 58, and a rheostat 59 or other regulating means is supplied in the circuit to focus the rays sharply. Electrostatic shielding 61 of copper or other high conductivity material is preferably provided for these coils.

Disposed about the tube are the coils 62 for producing vertical deflection of the rays and on either side of the tube the coils 63 for producing the horizontal deflection. Were the coils 56 and 57 not excited the functions of coils 62 and 63 would be interchanged. Both sets of coils are also provided with electrostatic shielding 66, but since these coils carry alternating current for scanning the image the shielding must not provide an unbroken electrical path around the coils. The scanning currents are produced by the oscillators 67 and 68.

A source 71 establishes the necessary potential difference between anode and cathode and a tap 72 is adjusted to make the target somewhat negative to the anode. A resistor 73 is included in series between the tap 72 and the target, and an amplifier 74 is bridged across the resistor.

An optical system, indicated schematically by the lens 76 throws an optical image upon the photo sensitive cathode, which emits electrons from each point on its surface in proportion to the illumination of that point. These electrons are accelerated in a direction parallel to the electrical axis by the electrostatic field between the cathode and the anode screen 36, the greater portion of them passing through the screen to be focused by the longitudinal field in a plane parallel to the cathode and including the aperture 41. The electrons passing through the aperture bombard the target 42 and liberate secondary electrons which are drawn to the housing 44, thereby setting up a current flowing through the resistor 73 and causing a potential drop thereacross which is amplified and passed on to the line by the amplifier 74.

Alternating currents of different frequencies in the coils 62 and 63 cause the electrical image to be deflected in two dimensions so that the image of each elementary area of the cathode in turn traverses the aperture, and a picture current is thereby set up which by proper apparatus may be re-converted into an optical image at a distant point.

Owing to the sharp focusing of the electrical image in the plane of the aperture 41, the definition of the transmitted picture is limited only by the size of the aperture, and pictures of remarkable clarity may therefore be obtained by the apparatus of my invention.

By placing a fluorescent screen in the focal plane of the tube as a detector of the rays, instead of the target, the action of the tube becomes directly visible, and this same arrangement together with a cathode of small area, con-

verts the tube into an apparatus suitable for the reception of pictures. Here also the focusing of the rays is a valuable feature.

By the term electrical axis I mean a line of indefinite length coinciding with a straight line of electrostatic force in the field between the cathode and the anode. Where the construction of the apparatus is symmetrical there may be an indefinite number of such lines, and the electrical axis will then be in their mean position. In any event the electrical axis is fully defined by the conformation and position of the anode and cathode.

I claim:

1. A cathode ray apparatus for electrically transmitting an entire optical image comprising an evacuated vessel, an electron emitting light sensitive cathode and an anode in said vessel between which an electrostatic field may be established, a coil external to said vessel for establishing a magnetic field substantially parallel to said electrostatic field and substantially uniform along the paths of the emitted electrons, and electrostatically shielded coils external to said vessel for establishing deflecting magnetic fields substantially normal to said first magnetic field.

2. An electrical discharge apparatus for electrically transmitting an entire optical image having an electrical axis defined by a light sensitive cathode and an anode, means for establishing a substantially uniform magnetic field in said apparatus substantially parallel to said axis, and means for establishing magnetic fields substantially normal to said first field and to each other.

3. A photo-electric tube comprising a light sensitive cathode, an anode adjacent said cathode to form therewith an electrostatic field, means for establishing a magnetic field substantially parallel to said electrostatic field, means for intercepting rays emitted from a limited area of said cathode, and means for deflecting all of the rays emitted from said cathode to cause them to scan said intercepting means.

4. A photo-electric tube comprising means for forming an optical image, means for forming an electrical image corresponding to said optical image, and means for focusing said electrical image in a plane spaced from the plane of said optical image.

5. A photo-electric tube comprising means for forming an optical image, means for forming an electrical image corresponding to said optical image, means for focusing said electrical image in a plane spaced from the plane of said optical image, and means in the plane of focus for diverting a limited portion of said electrical image.

6. A photo-electric tube comprising means for forming an optical image, means for forming an electrical image corresponding to said optical image, means for focusing said electrical image in a plane spaced from the plane of said optical image, means in the plane of focus for diverting a limited portion of said electrical image, and means for deflecting said electrical image.

7. A photo-electric tube comprising means for forming an optical image, means for forming an electrical image corresponding to said optical image, magnetic means for focusing said electrical image in a plane spaced from the plane of said optical image, means in the plane of focus for diverting a limited portion of said electrical image, and means for deflecting said electrical image in two dimensions.

8. A photo-electric apparatus comprising means for forming an optical image, means for forming an electrical image corresponding to said optical image, and means for focusing said electrical image in a plane spaced from the plane of said optical image, a screen having an aperture in the plane of focus for diverting the portion of the electrical image falling on said aperture, and a target for intercepting the component rays of said image passing through said aperture. 5
9. A cathode ray tube comprising a cathode having an extended electron emitting surface, means for forming a beam of cathode rays from said surface, means for establishing a magnetic field embracing the path of travel of said rays to focus an electrical image of said emitting surface in a geometrical surface spaced therefrom, and means for translating said electrical image positioned substantially in said focal surface. 10
10. A cathode ray apparatus comprising a cathode and an anode for generating cathode rays, means for detecting said rays, and means for establishing a magnetic field substantially coaxial with the path of said rays for reconverging rays from a specific portion of said cathode upon said detecting means substantially without admixture of rays from other portions of said cathode. 15
11. A cathode ray apparatus comprising a cathode and an anode for generating cathode rays, means for detecting said rays, and means including a coil coaxial with said anode and cathode for establishing a magnetic field substantially coaxial with the path of said rays for reconverging rays from a specific portion of said cathode upon said detecting means substantially without admixture of rays from other portions of said cathode. 20
12. A cathode ray apparatus comprising a cathode and an anode for generating cathode rays, means for detecting said rays, and means including an electrostatically shielded coil coaxial with said anode and cathode for establishing a magnetic field substantially coaxial with the path of said rays for reconverging rays from a specific portion of said cathode upon said detecting means substantially without admixture of rays from other portions of said cathode. 25
13. A cathode ray apparatus comprising an evacuated vessel, an electron-emitting cathode and an anode within said vessel between which an electrostatic field may be established, a coil external to said vessel positioned to produce a magnetic field substantially parallel to said electrostatic field and extending over substantially the entire path of electrons passing between said cathode and anode for directing electrons from specific portions of said cathode to specific portions of said anode, and other coils external to said vessel for establishing magnetic fields substantially normal to said first field for deflecting said electrons into other selected specific paths. 30

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