Nov. 23, 1937. P. T. FARNSWORTH 2,099,846

THERMIONIC OSCILLOGRAPH

Filed June 14, 1930

Fig. 1.

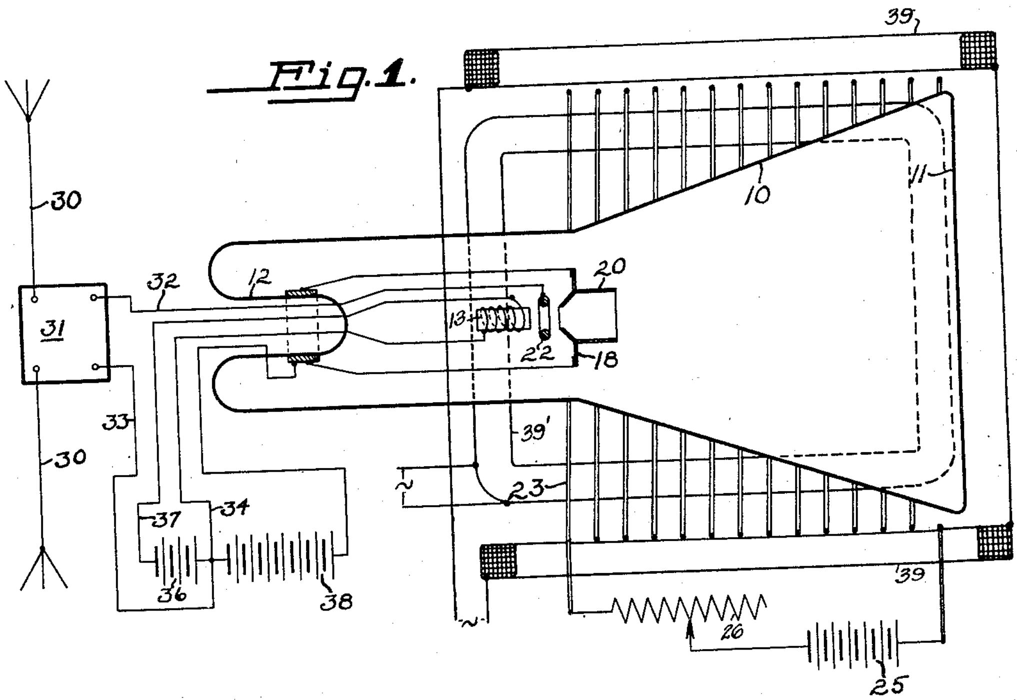


Fig. 2.

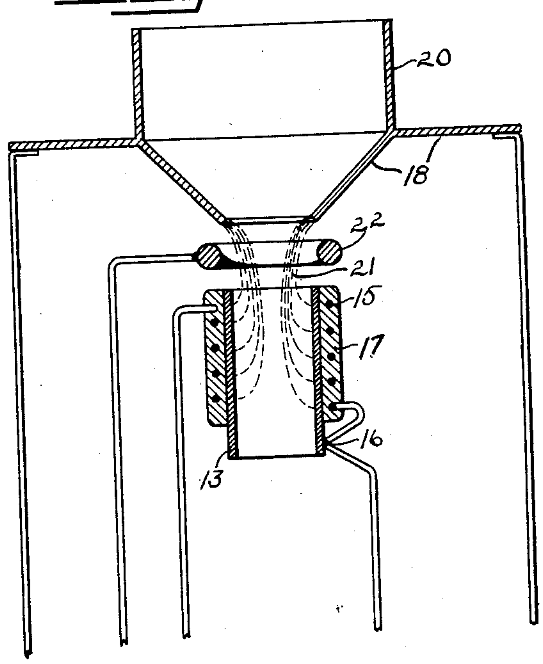
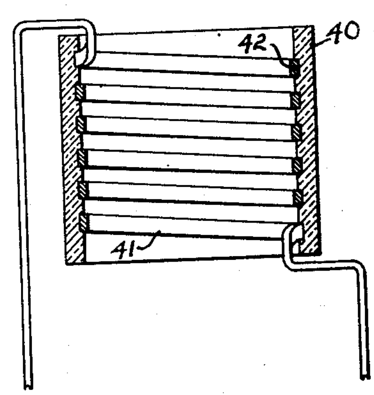


Fig. 3.



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2,099,846

THERMIONIC OSCILLOGRAPH

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Application June 14, 1930, Serial No. 461,111

8 Claims. (Cl. 250—27.5)

My invention relates to oscillights or cathode ray oscillographs such as are used in recording transient electrical phenomena, and more particularly to such oscillographs as used as receiving apparatus in television or the electrical projection of pictures.

Among the objects of my invention are: First, to provide an oscillight capable of producing an electron stream of high intensity; second, to provide an oscillight cathode such that substantially all of the electrons emitted thereby enter the useful electron stream; third, to provide an assembly of cathode and anode, or electron gun, which will produce an electron stream having a restricted area adjacent the plane of the anode and but slightly divergent therefrom; fourth, to provide an oscillight having means for re-converging a divergent electron stream to an electrical focus substantially in the plane of the screen upon which the stream leaves a visible trace.

My invention possesses numerous other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention, as I may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawing:

Figure 1 is a diagrammatic sectional view showing the oscillight of my invention together with certain of its associated circuits as used as a receiver in a television system.

Figure 2 is an enlarged axial sectional view of the cathode, anode and control electrode as used in the device of Figure 1.

Figure 3 is an enlarged axial sectional view of a modified form of cathode.

In a device of the character described, the primary object is to produce an electron stream or pencil of cathode rays whose trace or intersection with the fluorescent screen upon which they are received is an intense and highly concentrated spot. In order to produce such an electron stream, an "electron gun" is used. The conventional form of the electron gun is a thermionic filament, the electrons from which are attracted by a plate-shaped anode having an aperture therein through which a portion of the liberated electrons pass. The aperture is usually provided with a nozzle or coaxial tube of narrow bore, the sides of which receive such electrons as diverge from the axis of the stream at any material angle.

The pencil of cathode rays passing through the anode is "focused" on the fluorescent screen by proper adjustment of gas pressure, or electrostatic fields, or magnetic fields sharply localized in the plane of the electron gun, the effort being to prevent divergence in the pencil.

This device is relatively inefficient because of the large number of the emitted electrons which are caught upon and held by the anode, and hence never enter the useful stream. The "focus" of the beam of cathode rays is also a somewhat indeterminate quantity, varying greatly with the potential between anode and cathode and with the degree of vacuum within the device.

In the apparatus of my invention no attempt is made to limit the electron stream to a sharply parallel beam of electrons, but the electrons are allowed to diverge and are re-converged in the plane of the screen by a magnetic field substantially parallel to the path. A cylindrical cathode is used, coaxial with the electron stream, this cathode having an inner surface which emits electrons, and an outer surface from which the emission of electrons is suppressed. An annular anode is used, which is positioned to present a sharp inner edge toward the cathode, and the resultant electrostatic field between anode and cathode accelerates the electrons emitted by the cathode in such a manner that almost all of them pass through the aperture in a direction which is divergent, but only slightly so, the angle being of the order of 5° or less. As a result of this construction substantially all of the electrons emitted enter the stream, and are re-converged to a focus of the most constricted area of the stream substantially in the plane of the fluorescent or other screen by which their trace is made visible.

In detailed terms, the essentials of my invention are shown in diagrammatic form in Figure 1, the electron gun being enclosed in the usual flask-shaped envelope 10 having a flattened end 11 whereon a screen is formed which is adapted to show a visible trace of the electron stream. This screen may be of calcium tungstate, willemite, scheelite or other fluorescent material, or a photographic plate may be substituted.

In the opposite end of the envelope is a stem 12 upon which the elements of the electron gun are supported, usually by their lead wires. Since there are many well known modifications of such supporting elements, the mechanical details of this support are not shown.

The distinctive feature of the cathode used is that it is tubular in form and emits electrons from its inner surface only. The preferred form of the device is shown in enlarged detail in Figure 2, wherein the cathode proper is a tube 13 of nickel or other suitable material, whose inner surface is adapted to emit electrons. The electron emitting quality may be obtained by the depositing of a surface of alkaline earth oxide within the tube or by any other suitable or well known method.

Surrounding the outside of the tube is a heating element 15, one end of which is welded or otherwise connected to the tube at 16. The remainder of the winding is embedded in a suitable cement 17, which limits radiation from the heater, and prevents emission of electrons from the outer surface of the cathode. "Alundum" cement is suitable, but other refractory cements, obtainable on the open market, may be used.

The anode is mounted coaxially with the cathode. It may satisfactorily be formed by a plate of sheet-metal 18 which is dished to present a protuberant, truncated conical surface toward the cathode. The anode is thus annular in form, and its field to the cathode is primarily determined by the sharp inner edge which it presents thereto. If desired, a short collar 20 may be secured to the concave side of the anode, i. e., that side which is away from the cathode, in order to intercept the few stray electrons which may diverge at wide angles from the electron stream, owing principally to emission from portions of the apparatus which are not primarily intended to emit.

The shape of the electrostatic field between the anode and the emitting portions of the cathode is shown by the dotted lines 21. The force on the electrons emitted will be in the direction of these lines, but in no case will the electrons travel along the line where the line is curved. This is because the line shows the direction of the electron's acceleration and not the direction of its velocity. The paths of the electrons, due to the acceleration received from the field, form a pencil which converges slightly as it leaves the mouth of the tube 13, reaches its most constricted area in approximately the plane of the aperture in the anode, and then proceeds toward the fluorescent screen as a slightly divergent pencil. The amount of divergence in pencil of rays is small, and the velocity of each electron forming the pencil, in the direction of the axis of the device, is substantially the same.

Where a modulated electron stream is required, as in the case of an oscillight for television use, I prefer to use an annular control element 22, positioned between the anode and cathode.

It has been found a control electrode so placed will modulate the electron stream without materially affecting its configuration with regard to the size or position of the restricted area or the velocity of the stream.

The pencil of cathode rays emerging from the anode is re-converged to a focus by a magnetic field supplied by a solenoid or coil 23 which is substantially coaxial with the normal path of the electron stream and which surrounds substantially its entire length. Direct current from a source 25 is supplied to this coil, its intensity being regulated by a rheostat 26.

In my co-pending application, Serial No. 270,673, I have described at length the focusing action of such a field. The velocity of the divergent beam of electrons may be resolved into two components; one in the direction of the field, which is not affected thereby, and the other at right angles to the field. The transverse velocities are random in direction and magnitude, and, since the beam is but slightly divergent, are of small magnitude as compared to the longitudinal velocity.

Consider an electron having a charge e and mass m, whose velocity V is the resultant of a component V_L along the magnetic field and a component V_T transverse to the field of intensity ϕ. Only the latter component need be considered at present.

The charge e traveling at the velocity V_T is the equivalent of a current $I=eV_T$ insofar as its magnetic field is concerned. This effective current reacts with the field to produce a force $F=I\phi=eV_T\phi$. The force acts on the electron to produce an acceleration normal to the field and to V_T, the acceleration being

$$\frac{eV_T\phi}{m}$$

Being a normal acceleration it changes the direction of V_T but not its magnitude, and if ϕ is constant the path normal to ϕ is a circle, or, considering V_L, a helix, tangent to a line of force in the field.

The radius r of the helix is

$$\frac{mV_T^2}{F}=\frac{mV_T^2}{eV_T\phi}=\frac{mV_T}{e\phi}$$

The angular velocity with which the electron covers its circular path is

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

or, substituting for r and simplifying,

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

It will be seen that V_T does not enter this expression, and hence, if ϕ is constant, all electrons will have the same angular velocity, returning to tangency with the line of force passing through their origin in the same time $T=2\pi/\omega$.

All of the electrons in the pencil of rays have substantially the same longitudinal velocity V_L, and therefore, since they return to tangency in the same time, they also return to tangency in substantially the same plane. The result is that the originally divergent pencil of electrons is re-converged in this plane to form an image of the constricted area above mentioned, and by properly adjusting the strength of the field this plane may be made that of the screen 11.

Broad claims to this method of focusing are included in my co-pending application for Letters Patent above mentioned. The primary novelty in the present application of the theory to an oscillight, is that no attempt is made to provide an originally parallel or non-divergent electron stream; the stream is permitted to diverge at its source, but is re-converged into a sharp electrical image of that source.

In using the device as a television receiver, the radio wave is received on an antenna system 30, and is amplified and detected by the apparatus 31, which impresses the picture voltage through the lines 32, 33 and 34 between the cathode 13 and the control electrode 22. The heating element 15 is energized by the source 36 through the leads 34 and 37.

The emitted electrons are accelerated by the anode potential supplied by battery or other source 38.

The result is an electron stream, modulated by the required picture frequencies, and focused in the plane of the screen 11. Suitable coils 39, 39' are provided for deflecting the electron stream vertically and horizontally. These coils are energized from suitable high and low frequency sources to accomplish scanning of the picture field. It should be pointed out, however, that since the electron stream is focused on a line of force through its origin, the deflection produced by the coils is at right angles to the deflection where the focusing field is not used.

In Figure 3, I have shown a modified form of internally emitting cylindrical cathode which is equally as satisfactory as that shown in the preferred form of my device, but which is slightly more difficult to manufacture.

This modification comprises a refractory tube **40**, preferably of fused quartz, within which is wound a helical heating element **41** which acts as the electron emitter. Emission from the outer surface of this element is suppressed by its contact with the wall of the tube **40**. The inner wall of the tube preferably has a thread **42** formed therein, definitely to position the heating element within the tube. Although the cylindrical inner surface of this heating element is discontinuous, the action of the electrostatic field from the anode in accelerating and focusing the electrons therefrom is identical with that of the form of the device shown in Figure 2.

I claim:

1. An electron gun comprising a tubular cathode adapted to allow emission of electrons from its inner surface only, and an anode mounted substantially coaxially with said cathode and having a protuberant apertured surface presented thereto.

2. An electron gun comprising a tubular cathode adapted to allow emission of electrons from its inner surface only, and an anode of substantially conical form truncated to provide an aperture therethrough and positioned with said aperture substantially coaxial with said cathode.

3. A cathode ray apparatus comprising, a cathode comprising an internally emitting cylindrical surface, an annular anode positioned to present a sharp inner edge toward said cathode and substantially coaxial therewith to provide an electron stream having a constricted area adjacent said anode, a screen for receiving said electron stream and adapted to show a visible trace thereof, and means for establishing a field for reconverging said electron stream to form an electrical image of said constricted area substantially in the plane of said screen.

4. A cathode ray apparatus comprising, a cathode comprising an internally emitting cylindrical surface, an annular anode positioned to present a sharp inner edge toward said cathode and substantially coaxial therewith to provide an electron stream having a constricted area adjacent said anode, a screen for receiving said electron stream and adapted to show a visible trace thereof, and means for establishing a magnetic field substantially parallel to the axis of said cathode and anode to reconverge said electron stream forming an electrical image of said constricted area substantially in the plane of said screen.

5. A cathode ray apparatus comprising, a cathode comprising an internally emitting cylindrical surface, an annular anode positioned to present a sharp inner edge toward said cathode and substantially coaxial therewith to provide an electron stream having a constricted area adjacent said anode, a screen for receiving said electron stream and adapted to show a visible trace thereof, and a coil disposed substantially coaxially with said cathode and anode and surrounding the path of said electron stream for substantially the entire length thereof.

6. A cathode ray apparatus comprising means for generating a slightly divergent pencil of cathode rays, a screen positioned to receive said rays and adapted to show a visible trace thereof, and means for establishing a magnetic field substantially parallel to the path of said rays and adapted to reconverge said rays to a focus substantially in the plane of said screen.

7. A cathode ray apparatus comprising means for generating a slightly divergent pencil of cathode rays, a screen positioned to receive said rays and adapted to show a visible trace thereof, and a coil surrounding the path of said rays and substantially coaxial therewith and extending along substantially the entire length of said path to provide a magnetic field for reconverging the rays to a focus.

8. A cathode ray tube comprising a cathode member for producing an electron pencil, a cone-shaped anode having its apex through which the produced electron pencil is adapted to pass arranged substantially adjacent the cathode, a fluorescent screen upon which the electron pencil is adapted to impinge to produce luminous effects, and a magnetic coil positioned adjacent the base of the cone-shaped anode for producing under the influence of current flowing therethrough a magnetic field to cause a convergence upon the screen of the diverging electron stream issuing from the anode.

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