

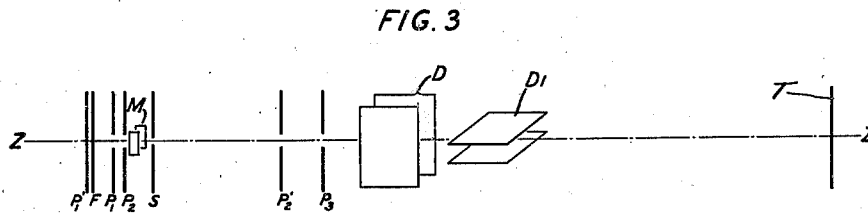
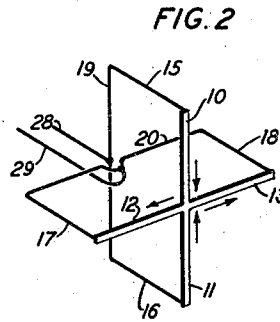
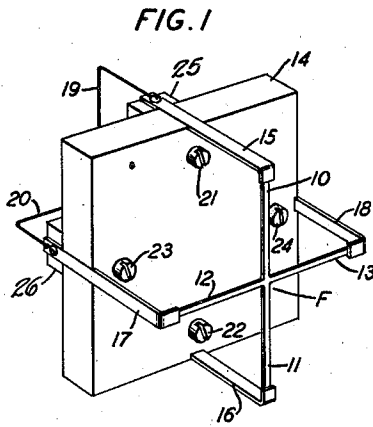
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C. J. DAVISSON

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ELECTRON DISCHARGE DEVICE

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INVENTOR
C.J. DAVISSON
BY *C. C. Sprague*
ATTORNEY

UNITED STATES PATENT OFFICE

2,117,709

ELECTRON DISCHARGE DEVICE

Clinton J. Davisson, Short Hills, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

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8 Claims. (Cl. 250—27.5)

This application relates to electron discharge devices and more specifically to electron emitting cathodes for cathode ray devices.

It is an object of this invention to provide a novel electron emissive cathode for a cathode ray device.

It is a further object of this invention to provide a novel cathode in which the electrostatic and electromagnetic fields due to currents therein and potential differences thereacross are substantially zero.

In the design of a condensing lens system for a television receiver tube such as, for example, that disclosed in a copending application of C. J. Davisson, filed December 30, 1936, Serial No. 118,277, an essential feature of the design is that an electron current density several times greater than that existing at the cathode be produced in a field-free space considerably removed from the cathode.

Electrons in general are considered as having an axially symmetric distribution about the electron optical axis, and the plane of maximum current per square centimeter occurs at that point along the axis where the "principal trajectories" are focussed. The electrons leave the cathode with thermal energy; those whose thermal energy is due to a thermal velocity normal to the cathode, i. e., parallel to the optical axis, pursue "principal trajectories". Those which have transverse thermal velocities, but leave the same point on the cathode will be grouped around that "principal trajectory" in a probability distribution. In the plane where all the "principal trajectories" are focussed, all these elementary probability distributions are superposed to form a single probability distribution, and this is the plane of maximum current intensity hereinafter called the S plane. It is not the plane in which an image of the cathode is formed.

Thus, if the cathode is equipotential and all fields are axially symmetric, the intensity in the S-plane is given by:

$$I = I_0 e^{-K^2(x^2+y^2)} \quad (1)$$

the optic axis being the Z axis, and I_0 being the intensity in amperes per square centimeter on the axis ($x=0, y=0$). The constant I_0 depends on the emission per square centimeter, the temperature of the cathode, and the beam voltage, while K^2 depends only on the cathode temperature and the beam voltage for a given geometry of the condenser lens system. The geometry of the lens

system is designed to make I_0 as large as practicable.

The emission per square centimeter from an oxide coated cathode is not as large as that from tungsten, and for this reason a tungsten ribbon filament has been used as a cathode. There are, therefore, magnetic and electric fields present, due to filament current and voltage, which are not axially symmetric, which destroy this symmetry as it is shown in Equation (1).

As television tubes ordinarily operate, a considerable potential gradient is applied perpendicular to the filament, and therefore the effect of filament voltage is negligible as compared with that of filament current. With a straight ribbon filament, a transverse velocity parallel to the filament is imparted to the electrons emitted by it, by the magnetic field due to the filament current. As a result, the "entrance pupil", to use an optical term, is considerably reduced, and this pupil "sees" an area of the filament to one side of the optic axis, while the location of maximum electron current density in the S-plane shifts to the other side of the optical axis. In addition, some distortion of the symmetrical distribution in Equation (1) occurs.

In this invention there is provided a filament in the form of a ribbon cross, which provides substantially zero magnetic and electric fields due to filament heating current along the optical axis, and only small fields in its immediate vicinity. Opposite ends of the cross are electrically connected, and current flows toward the center on one pair of said arms and away from the center on the other pair.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawing forming a part thereof, in which:

Fig. 1 shows the filamentary cathode in the shape of a ribbon cross;

Fig. 2 shows the method of making electrical connections to the filament shown in Fig. 1; and

Fig. 3 shows an electron gun system for a cathode ray device in which the filament of Fig. 1 may be used.

Referring more specifically to the drawing, Fig. 1 shows a filamentary cathode F in the shape of a ribbon cross for use in a cathode ray device. The filament F comprises four arms 10, 11, 12 and 13, the axes of which are preferably at right angles to each other. All four arms are preferably of equal length. The filament F, which is preferably made from a single sheet in order to make all parts of the filament of equal thickness

and of equal distance from other elements of the electron gun system which are located parallel to the surface of the filament F, is mounted on a suitable insulating supporting member 14 by means of conducting members 15, 16, 17 and 18. As will be seen with reference to Fig. 2, opposite

ly symmetric distribution of Equation (1) causing it to swell out slightly along the 45 degree lines. The x and y axes, of course, are chosen parallel to the arms of the cross.

If the ribbon cross is replaced for purposes of calculation by a filamentary cross, the field is:

$$\bar{H} = 0.1 I_a \left[\frac{yk - zj}{y^2 + z^2} \left(\frac{2x}{\sqrt{x^2 + y^2 + z^2}} - \left\{ \frac{x+L}{\sqrt{(x+L)^2 + y^2 + z^2}} + \frac{x-L}{\sqrt{(x-L)^2 + y^2 + z^2}} \right\} + \frac{xk - zi}{x^2 + z^2} \right) \frac{2y}{\sqrt{x^2 + y^2 + z^2}} - \left\{ \frac{y+L}{\sqrt{x^2 + (y+L)^2 + z^2}} + \frac{y-L}{\sqrt{x^2 + (y-L)^2 + z^2}} \right\} \right] \quad (2)$$

arms 10 and 11, and 12 and 13 are electrically connected together by means of suitable conducting members such as, for example, conducting straps 19 and 20. Leads 27 and 28 to a source of heating current (not shown) are connected to the mid-points of the straps 19 and 20 which are preferably equal and parallel. The conducting members 15, 16, 17 and 18 are supported on crossed insulating members 25 and 26 which are fastened to the base 14 by suitable screws 21, 22, 23 and 24.

The cathode F shown in Fig. 1 is adapted to be used in an electron optical system such as, for example, that shown in Fig. 3. The filament F is located between and parallel to a back electrode P1' and an accelerating focusing electrode P1. A negative voltage is applied between P1' and the cathode and a positive voltage is applied between P1 and the cathode, these potentials being of such values that the effect is to produce a uniform field between the two members to cause the electrons emitted from the four arms of the filament F to traverse paths which are substantially parallel to the optical axis Z-Z'. The diaphragm members P2, S and P2' are located in a metallic cylinder which thus places all three of these members at the same electrical potential which is positive with respect to that of P1. The distances of the diaphragms from the filament and the relative potentials applied thereto and to P1 cause electrons to be focussed in the plane of the diaphragm S. P3 is placed at a positive potential with respect to the potential of P2, S and P2' and cooperates with the diaphragm P2' to form a projection lens system to focus an image of the aperture in the plate S upon the screen or target T. The beam is modulated by a pair of deflecting plates M which vary the number of electrons incident upon the aperture in the plate S in accordance with the amplitude of signals. The beam is deflected in such a manner that it scans every elemental area of the field of the target T in turn by means of two sets of deflecting plates D and D1 to which are applied, respectively, saw-toothed wave forms of the proper frequency to produce this result. For a more complete description of the electron lens system briefly described above, reference may be made to the copending Davisson application hereinbefore mentioned.

In order to understand the operation of the ribbon cross filament, reference will be made to a mathematical analysis. The actual magnetic field for the ribbon cross cannot be calculated except by graphical integration. By symmetry, of course, the field along the axis itself is always zero. In the plane of the filament or cathode, it has only a Z-component which has a focusing effect which is maximum at $\theta = (2m+1)\pi/4$, θ being the cylindrical angular coordinate of the electron optical system. This distorts the axial-

where i, j, k , are unit vectors in the x, y, z directions respectively, and L is the length of each arm. If L is large compared to x and y , the terms involving L drop out, and there results

$$\bar{H} = 0.1 I_a \left[\frac{2xy}{\sqrt{x^2 + y^2 + z^2}} \left(\frac{1}{x^2 + z^2} + \frac{1}{y^2 + z^2} \right) k - \frac{2z}{\sqrt{x^2 + y^2 + z^2}} \left(\frac{x}{y^2 + z^2} + \frac{y}{x^2 + z^2} i \right) \right] \quad (2a)$$

Thus it is seen that the magnitude of the longitudinal component

$$|H_z|$$

is maximum along the 45 degree lines and its effect at all values of z is to distort in the same way as at $z=0$, discussed above.

However, the distortion due to the longitudinal component is probably small compared with that due to the transverse components. These cause to act on each electron a force

$$\bar{F} \propto \frac{-0.2zI_a}{\sqrt{x^2 + y^2 + z^2}} \left\{ \frac{xi}{y^2 + z^2} - \frac{yj}{x^2 + z^2} \right\} \quad (3)$$

The net effect of this force is to distort the circular equal-intensity lines of the distribution shown in Equation (1) into ovals of two-fold symmetry with major and minor axes the x - and y -axes, respectively. The major and minor axes interchange when the direction of the heating current is reversed.

Thus the cross filament replaces the symmetrical distribution shown in Equation (1) of the equipotential cathode with a distribution whose equal intensity lines are ovals of two-fold symmetry whose major axes are parallel to that pair of arms whose ends are connected to the positive terminal of the filament supply. Compared with a simple ribbon filament, the cross filament produces a distortion of the intensity distribution in the S-plane instead of a displacement of it. It is to be observed that the cross filament distorting forces are, for small x and y , always small compared with those associated with the straight ribbon.

A further advantage of the cross filament is that it tends automatically to reach a symmetrical temperature distribution in contrast to a straight filament in which, as is well known, temperature inequalities increase with aging. Thus, if R is the total filament circuit resistance, r_1, r_2 are the resistances of opposite arms of the cross, and E is the battery voltage,

$$I = \frac{E}{R} \cdot \frac{1}{1 + \frac{r_1}{r_2}}, \quad I_2 = \frac{E}{R} \cdot \frac{1}{1 + \frac{r_2}{r_1}} \quad (4)$$

while

$$\frac{P_1}{P_2} = \frac{r_2}{r_1} \quad (5)$$

that is, the power dissipated in each of the two opposite arms is in inverse ratio to their resistances. Careful consideration of this relation shows that non-uniformities tend to approach uniformity on aging, unless they are too extremely localized. There is one systematic departure from this tendency, that is, the heating due to the Thompson effect. On this account, one of the two pairs of opposite arms tends to be hotter than the other pair, and this tendency is accentuated on aging. But on the whole, experimentally, cross filaments show a remarkable tendency to assume a symmetrical distribution of temperature.

Cross filaments of the type disclosed above have been produced by electrolytic corrosion of .001 inch tungsten sheet and also by punching by means of a specially constructed punch. In some respects the latter method is preferable on account of its simplicity and the reproducibility of the ribbon cross as so produced. A disadvantage of this method, however, is that "curling" stresses are set up in the ribbon, so that there is a tendency for the cross to be distorted slightly on heating. Only occasionally has such distortion been serious, and in those cases there was some question as to whether the filament or the method of mounting was at fault.

When the filaments are produced by electrolytic corrosion, it is necessary to expose all parts of a piece of sheet tungsten, except a cross, to electrolytic action as uniform as possible. It proves extremely difficult to obtain sharp corners between the cross arms, and moreover slight variations occur in the width of the ribbon which forms the arms of the cross. It is, however, quite free from strain. Thus, each method has its advantages, with the punch method in general preferred.

The intensity distribution in the S-plane has been experimentally observed in two mutually perpendicular directions, and with a ribbon filament a distribution approximating Equation (1) is indicated with a constant K^2 characteristic, while with a cross filament a distortion of the type postulated in the theoretical discussion is actually observed.

To eliminate unbalance of any magnetic fields set up by the lead-in wires carrying filament current, it is desirable to mount opposite lead-in wires 15, 16, 17 and 18 parallel to each other and make them of similar length. It has been

observed that when care has not been taken in the placing of lead wires, stray fields are produced which cause distortion of the beam.

Various modifications may obviously be made without departing from the spirit of the invention, the scope of this invention being defined by the appended claims. It is to be understood that the invention is not limited in its use to the type of cathode ray device described above but may be used in any electron discharge device in which there is an advantage in eliminating the electrostatic and electromagnetic fields resulting from the current flowing through and the potential drop across circuits including an electrode member.

What is claimed is:

1. An electron emitting means for cathode ray tubes in the form of a single, flat, cross-shaped metallic element.

2. An electron emitting means for a cathode ray tube comprising a single element of tungsten fashioned in the shape of a cross.

3. An electron emitting means comprising a single element of tungsten fashioned in the shape of a cross from a tungsten sheet of the order of .001 inch in thickness.

4. In combination, a single piece cross-shaped electron emitting means, and means for electrically connecting together opposite points of the cross.

5. In combination, a single piece cross-shaped electron emitting means, and means for electrically connecting the four corners of said cross so that the electric and magnetic fields due to currents flowing through said electron emitting means and the potential differences across opposite points of said cross are substantially zero at the center of said electron emitting means.

6. In combination, a cross-shaped filament, a supporting member located parallel to the plane of said cross-shaped filament, and straps for supporting said filament from said support.

7. The combination claimed in claim 6 in which opposite straps are parallel to each other and all straps are substantially of the same length.

8. In combination, a flat cross-shaped electrode and four leads to said electrode, the leads being so arranged that the electric and magnetic fields due to currents through said leads and the potential differences across the leads are substantially balanced out.

CLINTON J. DAVISSON.