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CATHODE RAY TUBE SELECTIVE DEFLECTION AMPLIFIER USING A QUADRUPOLE LENS OF CRITICAL LENGTH

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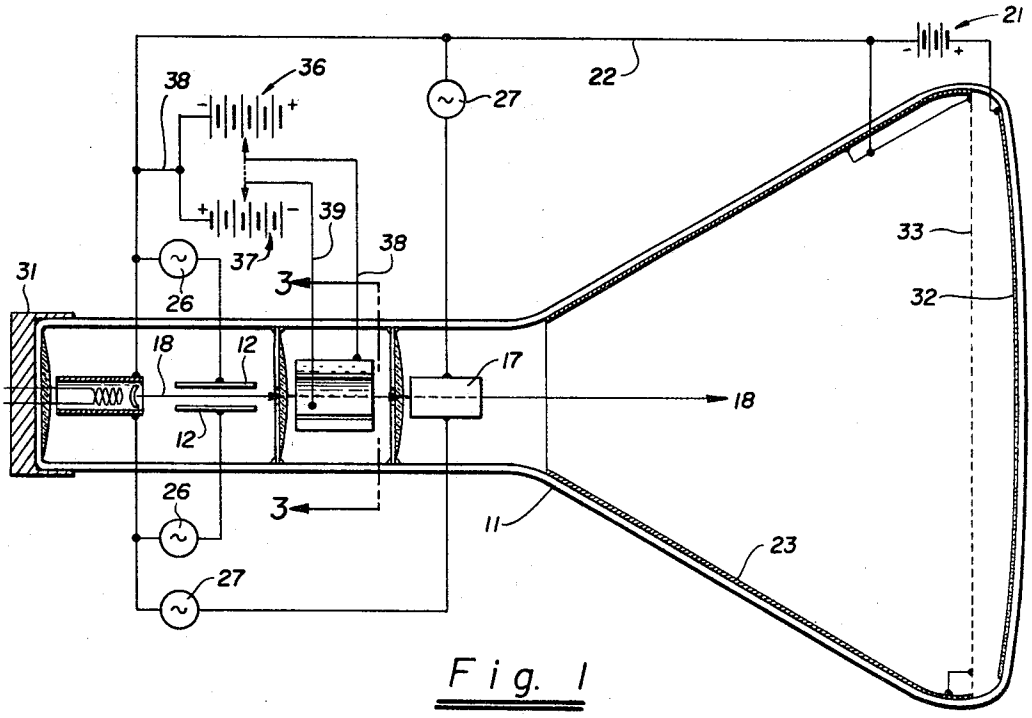


Fig. 1

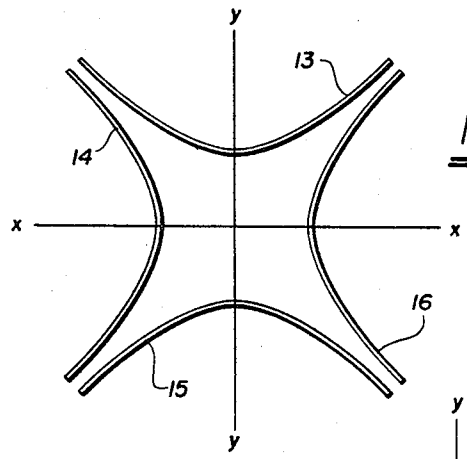


Fig. 3

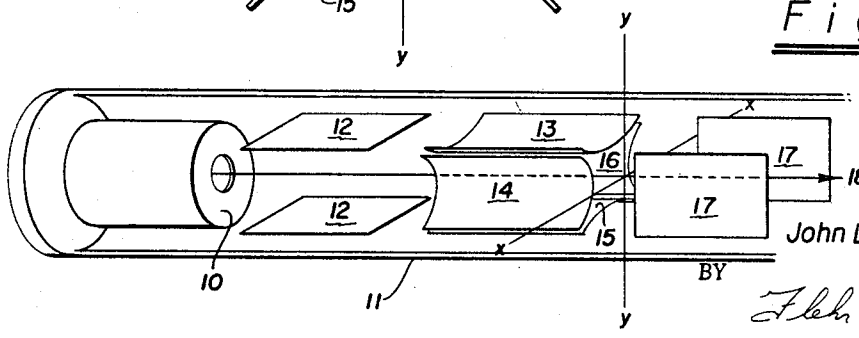


Fig. 2

INVENTOR.
John L. Worcester

BY

Fleh & Swain
Attorneys

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CATHODE RAY TUBE SELECTIVE DEFLECTION AMPLIFIER USING A QUADRUPOLE LENS OF CRITICAL LENGTH

John L. Worcester, Walnut Creek, Calif., assignor to E-H Research Laboratories, Inc., Oakland, Calif., a corporation of California

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ABSTRACT OF THE DISCLOSURE

A deflection amplifier for use in a cathode ray tube which comprises a quadrupole lens. The length of the quadrupole lens is critical and is determined by a formula, causing amplification of the deflection in one direction and no effect on deflection in a second direction. Opposite pairs of plates in the quadrupole lens have equal and opposite D.C. voltages impressed on them.

This invention generally relates to the deflection of electron beams in cathode-ray tubes.

A cathode-ray tube is generally a high vacuum tube which utilizes an electron gun acceleration and focusing system to send out a beam of electrons which travels to a screen portion of the tube. The source of electrons is a cathode within the electron gun which produces an electron space current. An assembly of cylindrical electrodes to which various control and accelerating direct current voltages are applied, forms the electron space current into a tightly packed beam and accelerates it toward the screen surface.

After passing from the electron gun the electron beam traverses the beam deflection portion of the tube which is usually located immediately following the electron gun. Within the deflection area electromagnetic fields are developed which cause the beam to be deflected. When an electric field is used it may be developed by pairs of vertical and horizontal deflection plates, axially placed astride the beam path. The electric fields created by the deflection plates generally acts to move the beam in a direction perpendicular to the direction of beam travel.

The deflection sensitivity and frequency response, the extent of display at the screen, and the resolution (spot size) are related through such parameters as the length and separation of the deflection plates, the energy of the beam and the length of the drift region. The design of a conventional cathode-ray tube necessitates an optimization of these parameters. Consequently, an increase in vertical deflection sensitivity can be gained by changing the physical and electrical parameters but such an increase tends to degrade the high frequency response, spot size, and adequate display size.

Accordingly, it is an object of the invention to provide a cathode-ray tube having improved sensitivity characteristics.

It is also an object of the invention to provide an improved vertical sensitivity characteristic in a cathode-ray tube while maintaining an adequate display size, spot size and a high frequency response.

It is another object of the invention to provide a charged particle deflection apparatus which will selectively amplify charged particle deflections.

It is another object of the invention to provide a cathode-ray tube of improved sensitivity and stability.

These and other objects of the invention will become more apparent from the following description in which the preferred embodiment of the invention has been shown in detail in conjunction with the accompanying drawings, of which:

FIGURE 1 is an elevational view partly in section of

a cathode-ray tube constructed according to the invention;

FIGURE 2 is an enlarged schematic view of the deflection system of the tube shown in FIGURE 1; and

FIGURE 3 is a transverse cross-section of the deflection amplifier according to the invention taken generally along the line 3—3 of FIGURE 2.

Referring now more particularly to the figures, there is shown an envelope **11** which serves to provide structural support for elements within the tube as well as the vacuum envelope.

An electron beam is ejected from an electron gun **10** and is generally directed along the path shown by line **18**. Hereinafter, reference to an undeflected beam path indicates the path shown by the line **18**. Two pairs of parallel plates oppositely disposed of the path **18** constitute the vertical and horizontal deflection means. The vertical deflection means **12** consists of the two parallel spaced-apart plates placed in a horizontal plane with respect to the undeflected beam path.

As shown, the electron beam **18** traverses the vertical and horizontal deflection means **12** and **17** as well as the deflection amplifier made up of plates, **13**, **14**, **15** and **16**. After passing through the entire deflection system the beam proceeds through a relatively field free region from the deflection system to the post deflection acceleration region formed between mesh **33** and screen **32**.

The mesh **33** and screen **32** are electrically maintained by voltage source **21** and conductor **22** so as to provide a post deflection acceleration. The screen **32** may be of any conventional conductive screen material such as aluminized phosphor. The wire mesh **33** may, for example, be made of 250 micron size conductive material and is maintained at the same potential as the electron gun by the conductor **22**. The difference between the wire mesh voltage and the voltage of the screen is generally high. Voltages in the range of 5 to 11 kilovolts are employed. This voltage is known as the post-deflection voltage and provides for brightness of screen illumination.

The electron gun **10** is a conventional electron gun which provides an accelerated electron beam. The acceleration voltage may be of the order of 1500 volts. The wire mesh **33** is maintained at a corresponding voltage by conductor **22**. In order to insure a field free region between the plates **17** and the mesh **33** a conducting surface **23** can be deposited on the inside of the envelope **11** between the plates **17** and the mesh **33** and is electrically connected to them. The conducting surface **23** can be made of aluminum. As a consequence, the region between the electron gun and the wire screen will be a field free region except for the small electromagnetic field contribution made by the deflection system itself. The vertical deflection means **12**, the horizontal deflection means **17**, and the deflection amplifier are electrically referenced to the voltage of the electron gun anode and the mesh. The voltages varied by variable electrical sources schematically illustrated at **26** and **27**.

The deflection amplifying apparatus of the present invention consists generally of the four deflection plates **13**, **14**, **15** and **16**. These plates make-up quadrupole or four pole lens arrangement which acts as a deflection amplifier.

More specifically and as shown in FIGURES 2 and 3 there is provided plates **13**, **14**, **15** and **16** which are arranged axially about the line defined by the undeflected electron beam **18**. The plates **13**, **14**, **15** and **16** are arranged so that two plates such as **14** and **16** generally are opposite each other in a horizontal manner comparable to the horizontal deflection plates **17**, while the other two plates such as **13** and **15** are opposite each other in a manner comparable to vertical deflection plates **12**.

Each of the amplifier plates is shaped in the form of a hyperbolic sheet, as shown in FIGURE 3. The equations

of a transverse line through the hyperbolic sheet may be written with respect to axes, x and y, shown in FIGURE 3, as

$$x^2-y^2=+A^2 \quad (1a)$$

$$x^2-y^2=-A^2 \quad (1b)$$

where (1a) is an equation representing one set of the hyperbolic sheets and (1b) is an equation representing the other set.

In operation the electron beam traverses the region between the plates **13**, **14**, **15** and **16**. Before traversing this region the electron beam has already undergone vertical deflection if any, by the action of the plate **12**. Through the region between the plates **13**, **14**, **15** and **16** the beam experiences forces due the voltages impressed upon these plates.

It is found that when plates **14** and **16** are made negative with respect to the reference voltage and plates **13** and **15** are made positive with respect to the reference voltage, that the vertical deflection will be amplified. By proper design this will not cause deamplification of the horizontal signal nor lessening of the horizontal deflection sensitivity.

The amount of positive and negative voltage applied is dependent upon the desired deflection amplification. The deflection amplifier plate voltages are substantially less than the electron gun acceleration voltage. For example, with an electron gun acceleration voltage of about 1500 volts, a deflection voltage of ± 54 volts with respect to the anode are found satisfactory. The deflection amplifier voltages are maintained at equal and opposite values by suitable means such as by an electronic power supply or batteries **36** and **37** and conductors **38** and **39**.

With deflection amplifier voltages at equal and opposite direct current values with respect to the accelerating anode the forces experienced by the electrons of the beam while traversing the region of the quadrupole lens may be described with reference to the axes x and y shown in FIGURE 2. These axes have been used to provide a mathematical reference to describe the position of a deflected beam with respect to the null or undeflected position **18**.

Making the simplifying assumption of infinitely long plates the electric potential within the region between plates is given by the following formula

$$V=k(x^2-y^2) \quad (2)$$

The electric field E and force F by such a potential is given by the relations

$$E=-\text{grad } V,\ F=eE=-e \text{ grad } V \quad (3)$$

When applied to the potential given by Equation 2 the forces in the directions x, y and z are given by:

$$F_x=-e\frac{\partial V}{\partial x}=-2ekx \quad (4)$$

$$F_y=-e\frac{\partial V}{\partial y}=2eky \quad (5)$$

$$F_z=-e\frac{\partial V}{\partial z}=0 \quad (6)$$

Equations 4 and 5 demonstrate that the electric forces in the x and y directions are independent of each other and proportional to the distances from the y and x axes respectively. The negative sign in Equation 4 indicates that the force in the horizontal direction F_x is an attractive force with respect to the y axis and since this force F_x is proportional to the x displacement, the electrons within the electron beam will oscillate periodically in a horizontal plane. By adjusting the length of the quadrupole lens or the voltage of the lens the electron beam can be made to exit from the lens system with the same angle as it entered. Consequently, the quadrupole lens can be made to have no effect on positioning or focusing of the electron beam in the x direction. The voltage sources

36 are provided with means for simultaneously adjusting their output which is indicated on the drawing by the ganged arrows. Since the period of oscillation is directly related to the magnitude of the potential on the deflection amplifier plates, it is possible to have the electron beam exit from the deflection amplifier at the same angle which it entered.

The positive sign of the force F_y presented in Equation 5 indicates that this is a repulsive force tending to accelerate any vertical displacement of the electron beam in passing through the quadrupole lens. Since the force F_y is a continuously increasing function it is apparent that the exit angle of the electron beam is proportional to the entrance angle. There is therefore provided an electron beam deflection system which acts as a negative lens with respect to vertical deflection and which may be made to act as a zero power lens with respect to horizontal deflections.

As a result a displacement and deflection resulting from the vertical deflection means **12** are amplified by the quadrupole independently of the value of x and dependent only upon the value y. I have also provided an apparatus which provides an increase in the vertical sensitivity without any corresponding change in the horizontal sensitivity.

Suitable conventional means (not shown) can be provided for the alignment of the undeflected electron beam in the center of the deflection system. Such means can consist of mechanical adjustment mechanism for moving the electron gun or an additional set of deflection plates for moving the electron beam.

I have therefore provided an increase in vertical sensitivity without affecting the horizontal sensitivity.

While the invention has been disclosed with respect to the preferred embodiment shown it will be apparent to those skilled in the art numerous variations and modifications may be made within the spirit and scope of the invention. Accordingly, it will be understood that the disclosure and description herein are purely illustrative and are not intended to be limiting.

For example, while I have shown the horizontal deflection plates positioned after the quadrupole lens, it is obvious that the horizontal deflection plates may alternatively be placed before the lens and no net deamplification of the horizontal sensitivity will result. The length of the lens and the voltage applied to the lens can still be chosen to cause the electron beam to exit from the lens with the same deffection and direction as it entered.

I claim:

1. A cathode ray tube comprising: an elongated envelope having a phosphor screen disposed at one end thereof, and an electron gun disposed at the other end thereof for directing an electron beam at said phosphor screen, said electron gun including an accelerating anode, said cathode ray tube further comprising an electrode disposed in the vicinity of said phosphor screen and maintained at substantially the same potential as the electron gun accelerating anode, further means for providing a post deflection accelerating voltage between said phosphor screen and said electrode, means for deflecting said electrode beam in first and second direction comprising first and second pairs of deflection plates disposed adjacent said electron gun, deflection amplifying means comprising a quadrupole lens arrangement of plates, each having a curved surface generally conforming to a hyperbolic sheet for amplifying the deflection produced by said first pair of deflection plates in said first direction, said quadrupole lens arrangement and said first and second deflection plates all being disposed axially about said electron beam path when the beam is in an undeflected condition, first means for maintaining one pair of said quadrupole lens deflection amplifier plates at a given D.C. potential and second means for maintaining the remaining pair of said quadrupole lens amplifier plates at a second D.C. potential of equal magnitude and opposite polarity to said first potential, each of said quadrupole

lens deflection amplifier plates having a length given by the formula

$$L_0 = nv_0\pi\sqrt{\frac{ma^2}{2eV_0}}$$

where:

L_0=the length of each of said quadrupole lens plates
n=an integer
v_0=the velocity of the electrons in said electron beam
m=the mass of an electron in said electron beam
a=the distance of each plate of said quadrupole lens from the undeflected path of said electron beam
e=the charge on an electron
v_0=the absolute voltage on the plates of said quadrupole lens deflection amplifier.

whereby any deflection of said electron beam in said second direction is substantially unaffected by said quadrupole deflection amplifier.

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ROBERT L. GRIFFIN, *Primary Examiner.*

DAVID G. REDINBAUGH, JOHN W. CALDWELL, *Examiners.*

T. A. GALLAGHER, R. K. ECKERT, *Assistant Examiners.*