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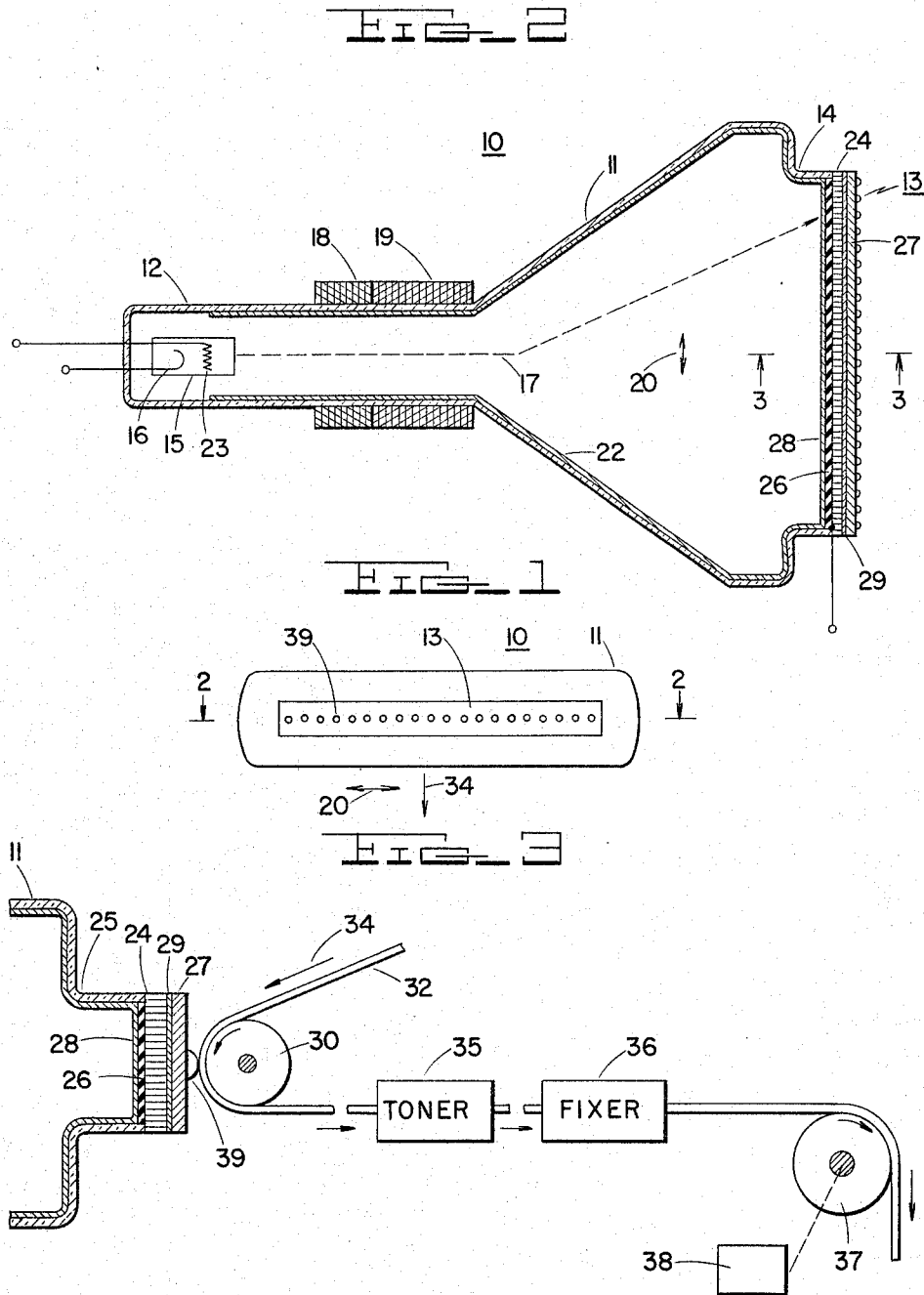
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PRINTING CATHODE RAY TUBE USING PHOTOCONDUCTIVE LAYER

Filed Nov. 29, 1963

2 Sheets-Sheet 1



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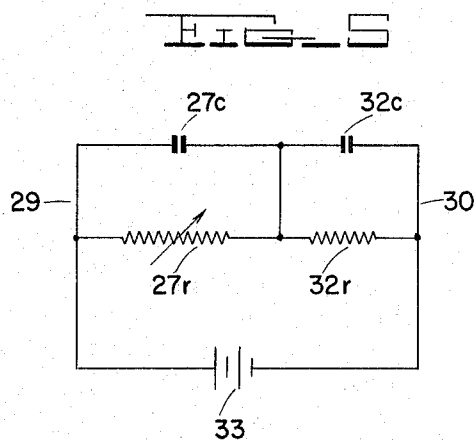
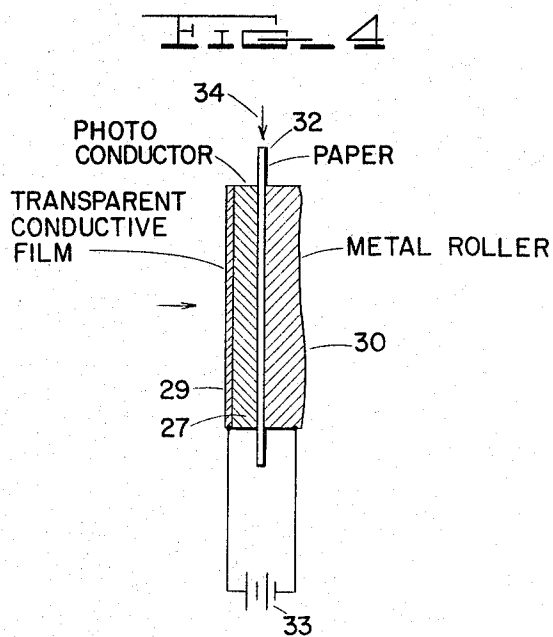
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PRINTING CATHODE RAY TUBE USING
PHOTOCONDUCTIVE LAYERLozure G. Wolfgang, Fort Wayne, Ind., assignor to Inter-
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14 Claims. (Cl. 178-6.6)

This invention relates generally to apparatus for converting an electrical signal into a corresponding optical image and for recording that image in visual form, and more particularly to electronic high speed printing tube apparatus.

Conventional forms of high speed printers incorporate a tube of the cathode ray type, a time-based electrical signal being used to modulate a scanning electron beam, which in turn is used to produce a charge pattern directly upon printing paper or other suitable dielectric material, or upon a photoconductive drum or belt. The charge pattern is then rendered visible through xerographic techniques in which several variations are possible, i.e., the charge pattern may be toned and affixed in situ; or may be transferred to another media, toned and affixed thereto; or the charge pattern may be toned in situ, and the resultant pattern transferred to another media and affixed thereto.

There are two general types of electrostatic printers distinguished by the method by which the charge in the electron beam is transferred to charge the printing paper. The first type utilizes direct charge transfer in which the electron beam itself supplies electrons for charging the surface of the dielectric media. Such tubes conventionally incorporate a plurality of wires extending through the faceplate of the tube, these wires being impinged by the electron beam and transferring the charge out of the tube for directly charging the printing paper. Tubes of this type, however, suffer a distinct disadvantage in that a current gain of less than unity exists occasioned by secondary emission from the wires which transfer the charge out of the tube and charging of the wire capacitances in parallel with the paper capacitance, conventional tubes of this type have a current gain of about 0.4.

The second type of tube utilizes indirect charge transfer in which the charge in the electron beam is used to excite charge carriers in a photoconductive material. In conventional printing tubes of the indirect charge transfer type, the electron beam excites a phosphor which is optically coupled by a suitable lens system to the photoconductor, generally in the form of a moving drum or belt; radiation from the phosphor produces charge carriers in the photoconductive material and by this means a charge pattern is developed on the surface of the photoconductor. This charge pattern on the photoconductor is then transferred to printing paper or other suitable dielectric media prior to toning by suitable methods or may be toned and then transferred as in conventional xerography.

It has been proposed to employ with such indirect charge transfer tubes a paper coated on one side with photoconductive material, the charge thereon being suitably toned directly to produce the visible image. Such methods as described, commonly referred to as xerographic techniques, do not utilize bulk photoconductivity and such systems therefore, are limited to a quantum gain of unity.

In order to obtain a satisfactory black and white print, a certain charge density, i.e., about 3.6×10^{-7} coulomb per square inch, must be added to or removed from the printing paper. It will thus be seen that with a current gain of unity or less in the photoconductor, substantial

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electron beam current is required in order to provide the requisite charge density. It is therefore desirable to provide an electrostatic printing tube in which a current gain is realized in a photoconductor thus permitting printing with lower level electron beam current, in turn reducing the electron beam spot size and thus increasing the resolution, reducing the power requirements of the cathode ray tube and its associated electronics, and permitting printing at high speeds.

It is accordingly an object of this invention to provide improved electrostatic printing tube apparatus.

Another object of the invention is to provide improved electrostatic printing tube apparatus of the indirect charge transfer type.

A further object of the invention is to provide improved electrostatic printing tube apparatus of the indirect charge transfer type in which current gain is realized.

In accordance with the broader aspects of this invention, a transparent conductive layer is applied directly to the faceplate assembly of the tube and a stationary photoconductor is in turn applied directly to the transparent conductive layer; in a preferred embodiment, a fiber-optics faceplate is employed to couple the phosphor output to the photoconductor in order to obtain the maximum optical efficiency with minimum loss in resolution. A conductive member is closely spaced from the photoconductor and a source of potential is coupled across the transparent conductive layer and the conductive member. The printing paper or other dielectric media is then merely drawn between the photoconductor and the conductive member so that an electrostatic charge image is directly produced in the paper in response to the incremental resistance of the photoconductor, which in turn is responsive to the incremental phosphor output. The storage function is thus moved from the photoconductor to the printing paper itself, which not only eliminates the photoconductive-coated paper or photoconductive drum or belt of prior indirect charge or transfer tubes, but more importantly employs the bulk photoconductivity of the photoconductor to realize a current gain; with this arrangement, a current gain as high as 240 may be realized. This current gain in turn permits increased paper speed, i.e., printing rate and/or the width of the paper being printed, and/or a reduction in the electron beam current thus reducing spot size and providing increased resolution.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an end view of the improved printing tube of the invention;

FIG. 2 is a cross-sectional view of the printing tube taken along the line 2-2 of FIG. 1;

FIG. 3 is a fragmentary view, partly in cross-section illustrating the printing apparatus employed with the tubes of FIGS. 1 and 2;

FIG. 4 is a fragmentary diagram useful in explaining the mode of operation of the invention; and

FIG. 5 is a schematic diagram showing the equivalent circuit of FIG. 4.

Referring now to the figures of the drawing, the printing tube of the invention, generally indicated at 10, comprises an evacuated envelope having a funnel portion 11 with its small end joined to a neck portion 12, and a faceplate assembly 13 sealed to the large end 14 of the funnel portion 11. In the illustrated embodiment wherein scanning in one direction is accomplished by movement

of the printing paper, as will be hereinafter more fully described, and thus it is only required that the electron beam be deflected in one direction perpendicular to the direction of movement of the paper, the funnel portion 11 is preferably flattened to provide an elongated cross-sectional configuration at its large end 14 in order to reduce space requirements, as best seen in FIG. 1.

A conventional electron gun 15 is positioned within neck portion 12 and includes a conventional cathode 16 for forming and directing electron beam 17 toward faceplate 13. Conventional focusing and deflection coils 18 and 19 are positioned coaxially upon neck portion 12 respectively to provide a highly focused electron beam and to deflect the beam in the direction shown by the arrows 20 in FIGS. 1 and 2. The interior surfaces of the neck portion 12 and funnel portion 11 may be coated with a suitable conductive material 22, such as aquadag or aluminum, as is well known to those skilled in the art. Electron gun 15 also includes a conventional control grid 23 adapted to be connected to a source of time-based signals for modulating the electron beam 17 in response thereto.

The faceplate assembly 13 comprises an elongated fiber-optic sheet 24, which in an embodiment for printing upon paper 8½ inches wide may have a rectangular configuration of ½ inch by 9 inches, hermetically sealed, such as by means of a glass frit seal, to protruding section 25 of the funnel portion 11.

It will be understood that the fiber-optic material from which sheet 24 is formed is not a part of the invention, such fiber-optic materials being described in numerous technical articles including an article entitled "Fiber Optics" by Narinder S. Capany, appearing in Scientific American for November 1960. Optical fibers are essentially small diameter rods of transparent dielectric material, such as 1 to 2 mil diameter glass fibers. Light conduction along transparent rods is well known, and when a large number of such rods or fibers are sealed together in the form of a sheet having flat opposite sides and with the fibers extending transversely between the sides, an optical image is transmitted from one side to the other with high light efficiency.

The side of the fiber-optic sheet 24 facing the electron gun 15 is coated with a layer 26 of a high resolution phosphor chosen to have spectral characteristics matching those of the photoconductive layer 27, to be hereinafter described. A P-2 or P-20 phosphor is suitable for use with a cadmium sulphide photoconductor and a red phosphor such as P-22R as suitable with cadmium selenide photoconductive material.

For increasing the brightness of the optical image produced in the phosphor layer 26 in response to impingement by the electron beam 17 and also for increasing resistance to ion bombardment, aluminum film 28 may be deposited upon the phosphor, as is well known to those skilled in the art. Film 28 may extend inside the funnel 11 forming the conductive wall coating 22 above-described, or may extend only a short distance making contact with the conductive wall coating. It will now be readily seen that the optical image produced in the phosphor layer 26 in response to the electron beam 17 will be transmitted by the fiber-optic sheet 24 to its outer surface with minimum loss of resolution.

The outer side of the fiber-optic sheet 24 is coated with a transparent conductive film 29 such as stannous oxide or Nesa to which electrical contact may be made. Layer 27 of photoconductive material is deposited upon a transparent conductive layer 29.

It will now be seen that the light image transmitted through the fiber-optic sheet 24 from the phosphor layer 26 is in turn transmitted through the transparent conductive layer 29 to the photoconductive layer 27. The photoconductor 27 has high dark resistance and low light resistance, and thus it will be seen that its incremental resist-

ance will be varied in response to the incremental light output of the photophor layer 26.

A roller 30 is provided formed of conductive material and closely spaced from the outer surface of the photoconductive layer 27. An elongated sheet 32 of paper or other suitable dielectric material is provided on a suitable roll (not shown) and is passed around roller 30 so as to be spaced from the outer surface of photoconductive layer 27, as best seen in FIG. 3.

Referring now additionally to FIGS. 4 and 5, a suitable source 33 of potential, such as 400 volts, is coupled across a transparent conductive layer 29 and the conductive roller 30. It will now be seen that a circuit is provided between conductive layer 29 and conductive roller 30 comprising the shunt capacitance 27c and resistance 27r of the photoconductive layer 27, serially connected with the shunt capacitance 32c and resistance 32r of the paper 32. It will be observed that the resistance 27r of the photoconductor 27 is variable from a very high value under dark conditions to a much lower value in response to incident light, and it will also be observed that the shunt resistance 32r of the paper 32 is likewise very high. By virtue of the extremely high dark resistance 27r of the photoconductive layer 27, and with the sheet of paper 32 moving in the direction shown by the arrow 34, the shunt capacitance 32c of the paper 32 will not be appreciably charged in the absence of incident light upon the photoconductor 27. However, in response to impingement of light upon the photoconductor 27, its shunt resistance 27r falls to a low value, thus applying substantially all of the voltage of source 33 across shunt resistance 32r of the paper 32 and in turn charging shunt capacitance 32c. It will thus be seen that when the paper is moved in the direction 34, a charge pattern will be scanned onto the moving paper sheet 32 in response to the light image impressed upon the photoconductive layer 27 from the phosphor layer 26; it will be seen that with the paper continually moving, new uncharged paper is continually introduced between the conductive roller 30 and the photoconductive layer 27, so that the incremental capacitance 32c of the paper exits from the roller 30 and photoconductive layer 27 in a charged condition. It will also be readily apparent that in the alternative, the paper 32 may first be charged to a predetermined potential and the photoconductive layer 27 employed to discharge the paper in response to the light image.

It will now further be seen that the requisite rectilinear scanning is provided by virtue of the movement of the sheet of paper 32 in the direction 34 and the deflection of the beam 17 in direction 20 perpendicular to direction 34, as best seen in FIG. 1.

The paper 32 having a charge pattern thereon may then be moved sequentially through a suitable chamber 35 for applying a suitable toner and then through another suitable chamber 36 for applying a suitable fixer in accordance with conventional xerographic techniques. The sheet of paper 32 may be moved in the direction 34 by means of any conventional mechanism, such as a suitable roller 37 driven by a suitable drive motor 38.

The outer surface of the photoconductive layer 27 preferably has a plurality of relatively small metallic islands 39 formed thereon in order to reduce abrasion caused by the sheet of paper 32 moving across the photoconductive surface 27 in contact therewith or in close proximity thereto. The outer surface of the photoconductive layer 27 and/or the metallic islands 39 are preferably formed to a flatness of optical quality and in order to achieve this, the surfaces of the fiber-optic sheet 24 are preferably ground to a flatness of optical quality.

In a specific embodiment of this invention, the fiber-optic sheet 24 may have a thickness on the order of ¼ inch and the photoconductive layer 27 may have a thickness varying from a few microns to a few thousandths of an inch, depending upon the specific photoconductive material employed.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

What is claimed is:

1. Apparatus for converting an electrical signal into a corresponding optical image and for recording said image upon a dielectric media comprising: a cathode ray tube having faceplate means, means for generating an electron beam and for directing the same onto said faceplate means, means for modulating said beam in response to said signal, and means for deflecting said beam thereby to scan the same over said faceplate means; a layer of phosphor material on the inner surface of said faceplate means and impinged by said beam whereby an optical image is provided in response to said beam; a transparent conductive layer on the outer surface of said faceplate means; a layer of photoconductive material on said transparent conductive layer, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the resistance thereof in response to said optical image; a sheet of dielectric material having one surface adjacent said photoconductive layer; a conductive member adjacent the opposite surface of said dielectric sheet; means for impressing a potential across said conductive member and said conductive layer whereby a charge pattern is developed between said surfaces of said dielectric sheet in response to the resistance of said photoconductive layer; and means for converting said charge pattern into a visible image.

2. The apparatus of claim 1 further comprising means for moving one of said beam and said dielectric sheet in a second direction thereby to provide two-dimensional scanning of said dielectric sheet.

3. The apparatus of claim 2 wherein said second direction is perpendicular to said first direction and said dielectric sheet is elongated in said second direction, and wherein said moving means moves said dielectric sheet in said second direction.

4. The apparatus of claim 1 wherein said converting means comprises means for applying a toner material to said dielectric material sheet with said charge pattern thereon, and means for applying a fixer material to said dielectric sheet.

5. Apparatus for converting an electrical signal into a corresponding optical image and for recording said image upon a dielectric media comprising: a cathode ray tube having faceplate means, means for generating an electron beam and for directing the same onto said faceplate means, means for modulating said beam in response to said signal, and means for deflecting said beam in a first direction thereby to scan the same over said faceplate means; said faceplate means comprising a fiber-optic sheet having an inner surface facing said beam generating means and an outer surface and with the fibers thereof extending generally transversely between said surfaces, a layer of phosphor material on said inner surface and impinged by said beam whereby an optical image is provided in response to said beam, said fiber-optic sheet transmitting said optical image to said outer surface thereof, a transparent conductive layer on said outer surface, and a layer of photoconductive material on said transparent conductive layer, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the resistance thereof in response to said optical image; a sheet of dielectric material having one surface adjacent said photoconductive layer; a conductive member adjacent the opposite surface of said dielectric sheet; means for impressing a potential across said conductive member and said conductive layer whereby a charge pattern is developed between said surfaces of said dielectric sheet in response to the resistance of said photoconductive layer; means for moving one of said beam and

said dielectric sheet in a second direction thereby to provide two dimensional scanning of said dielectric sheet; and means for converting said charge pattern into a visible image.

6. Apparatus for converting a time-based electrical signal into a corresponding optical image and for recording said image upon a dielectric media comprising: a printing cathode ray tube comprising an enclosing envelope having a neck portion at one end and a funnel portion at its other end, a faceplate assembly closing said funnel portion, said faceplate assembly being elongated in a first direction, an electron gun in said neck portion for generating an electron beam and for directing the same toward said faceplate assembly, said electron gun including means for modulating said beam in response to said signal, means for sharply focusing said beam, and means for deflecting said beam in said first direction thereby to scan the same over said faceplate assembly; said faceplate assembly comprising a fiber-optic sheet having a flat inner surface facing said electron gun and a flat outer surface and with the fibers thereof extending generally transversely between said surfaces, a layer of phosphor material on said inner surface and impinged by said beam whereby an optical image is provided in response to said beam, said fiber-optic sheet transmitting said optical image to said outer surface thereof, a relatively thin layer of transparent conductive material on said outer surface; and a layer of photoconductive material on said transparent conductive layer, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the resistance thereof in response to said optical image; a relatively thin sheet of dielectric material elongated in a second direction perpendicular to said first direction and having a transverse portion of one surface thereof adjacent said photoconductive layer; a conductive member engaging the other surface of said dielectric sheet opposite from said transverse portion; means for impressing a potential across said conductive layer and said conductive member whereby a charge pattern is developed between said surfaces of said dielectric sheet in response to the incremental resistance of said photoconductive layer; means for moving said dielectric sheet in said second direction thereby continually to introduce uncharged dielectric sheet between said conductive layer and said conductive member and cooperating with said deflecting means to provide rectilinear scanning of said sheet; and means for converting said charge pattern into a permanent visible image on said dielectric sheet.

7. The apparatus of claim 5 further comprising a plurality of relatively small metallic islands on said photoconductive layer and respectively engaging said one surface of said dielectric sheet.

8. A printing cathode ray tube comprising: faceplate means; means for generating an electron beam and for directing the same onto said faceplate means, means for modulating said beam in response to an electrical signal; and means for deflecting said beam thereby to scan the same over said faceplate means; a layer of phosphor material on the inner surface of said faceplate means and impinged by said beam whereby an optical image is provided in response to said beam; a transparent conductive layer on the outer surface of said faceplate means; and a layer of photoconductive material on said transparent conductive layer, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the incremental resistance thereof in response to said optical image.

9. A printing cathode ray tube comprising: faceplate means; means for generating an electron beam and for directing the same onto said faceplate means; means for modulating said beam in response to an electrical signal; and means for deflecting said beam thereby to scan the same over said faceplate means; said faceplate means comprising a fiber-optic sheet having an inner surface

facing said beam generating means and an outer surface and with the fibers thereof extending generally transversely between said surfaces, a layer of phosphor material on said inner surface and impinged by said beam whereby an optical image is provided in response to said beam, said fiber-optic sheet transmitting said optical image to said outer surface thereof, a transparent conductive layer on said outer surface, and a layer of photoconductive material on said transparent conductive layer, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the incremental resistance thereof in response to said optical image.

10. The tube of claim 9 wherein said deflecting means deflects said beam in one direction only.

11. The tube of claim 9 further comprising a conductive member closely spaced from said photoconductive layer, and a source of potential coupled across said transparent conductive layer and said conductive member.

12. A printing cathode ray tube comprising: an evacuated envelope having a neck portion at one end and a funnel portion at its other end, and a faceplate assembly sealed to the end of said funnel portion remote from said neck portion and closing the same, said funnel portion being generally flat in cross-section and being elongated in one direction at said end thereof; an electron gun in said neck portion for generating an electron beam and directing the same toward said faceplate assembly, said electron gun including means for modulating said electron beam in response to an electrical signal; means for sharply focusing said beam; and means for deflecting said beam in said one direction thereby to scan the same over

said faceplate assembly; said faceplate assembly comprising a fiber-optic sheet elongated in said one direction and having a flat inner surface facing said electron gun and a flat outer surface and with the fibers thereof extending generally transversely between said surfaces, a layer of phosphor material on said inner surface and generally coextensive therewith, said phosphor layer being impinged by said beam whereby an optical image is provided in response thereto, said fiber-optic sheet transmitting said optical image to said outer surface thereof, a relatively thin layer of transparent conductive material on said outer surface and generally coextensive therewith, and a layer of photoconductive material on said transparent conductive layer and generally coextensive therewith, said transparent conductive layer transmitting said optical image to said photoconductive layer for varying the resistance thereof in response to said optical image.

13. The tube of claim 12 further comprising a plurality of relatively small metallic islands on said photoconductive layer on the side thereof remote from said conductive layer, said islands being spaced apart generally along a line extending in said one direction.

14. The tube of claim 12 further comprising a conductive member closely spaced from said photoconductive layer, and a source of potential coupled across said conductive layer and said conductive member.

No references cited.

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