Feb. 3, 1959 M. V. KALFAIAN 2,872,613

COLOR IMAGE SCREEN UTILIZING ELECTROLUMINESCENCE

Filed Sept. 7, 1955 2 Sheets-Sheet 1

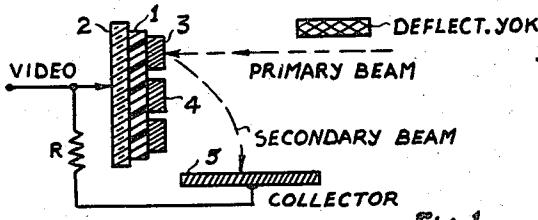


Fig. 1

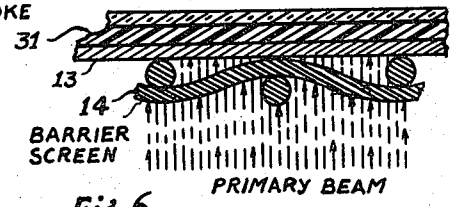


Fig. 6

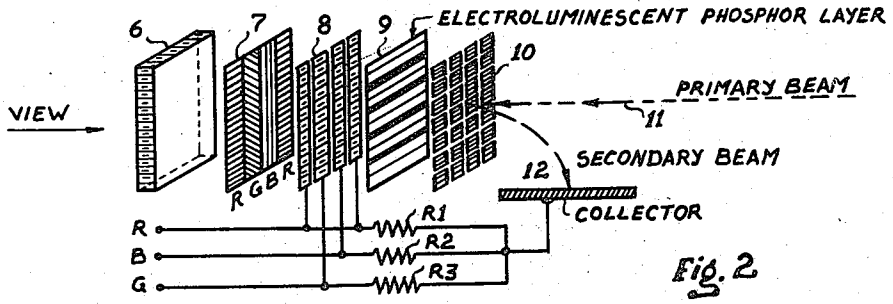


Fig. 2

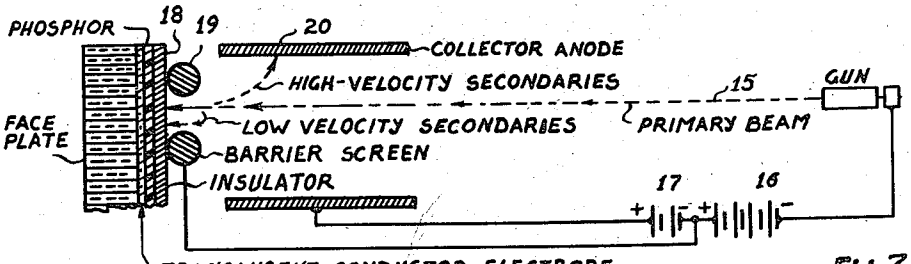


Fig. 3

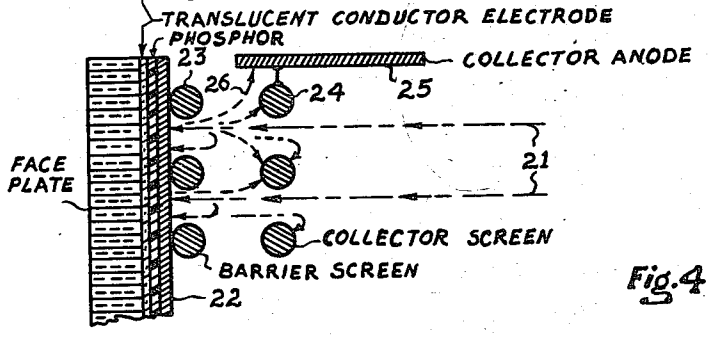


Fig. 4

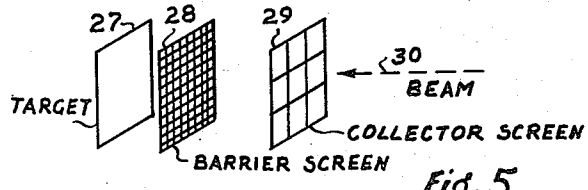


Fig. 5

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COLOR IMAGE SCREEN UTILIZING ELECTROLUMINESCENCE

Filed Sept. 7, 1955 2 Sheets-Sheet 2

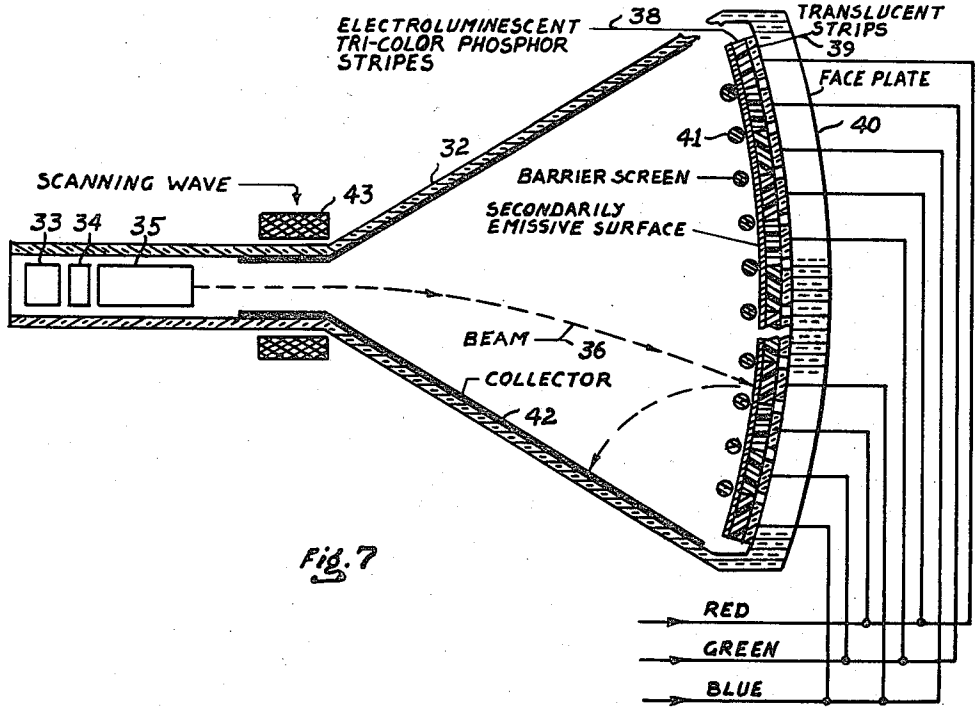


Fig. 7

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United States Patent Office

2,872,613

Patented Feb. 3, 1959

2,872,613

COLOR IMAGE SCREEN UTILIZING ELECTROLUMINESCENCE

Meguer V. Kalfaian, Los Angeles, Calif.

Application September 7, 1955, Serial No. 532,852

2 Claims. (Cl. 315—12)

This invention relates to television systems and is particularly concerned with devices for electro-optical image formation in natural colors utilizing electroluminescence as the source of optical illumination. Its main object is to provide an electroluminescent color screen, which may be activated by an electron beam for the production of images in natural colors. Another object is to provide an electroluminescent color screen, the primaries of which may be selectively activated within the spot-area of a single electron beam, in either simultaneous or sequential additive systems, without altering the direction of the beam from its normal deflection of forming a scanning raster on the image screen.

Production of light by electroluminescence has been known previously, and its practicality is shown by Mager in U. S. Patent No. 2,566,349, September 4, 1951. The electroluminescent cells, or luminous capacitors as they may be called, consist of parallel plate electric conductors with a suitable electroluminescent phosphor dispersed therebetween. Normally, one of the conductors is made translucent, whereby the light emitted by the phosphor cells may pass therethrough. The light emission of these phosphor cells is effected by an alternating electric field passing through them, as for example, by the application of alternating voltage upon the two conductor plates from an outside source. The intensity of light given off by an electroluminescent cell is a function of the applied voltage as well as the frequency of the applied voltage, but as the frequency is increased a point is reached where higher frequencies do not increase the intensity of light emission. This limitation may be attributed to the slow transfer of energy from the electric field to the activator centers of presently available electroluminescent phosphor cells; but more suitable phosphor materials may be found for high frequency excitation with high efficiency.

The thickness of the electroluminescent screen is usually made between 10 to 100 microns thick, and therefore, it is possible to concentrate the luminescence into a very small spot area between two conductors of this size without causing objectionable corona of the electric field between the two conductors. It is accordingly possible to place the electroluminescent screen between first and second plurality of spaced parallel strip-like conductor electrodes, running along lines of 90 degree relation with respect to each other, and luminesce any spot area of the screen where two of the first and second strip-like electrodes intersect each other, by applying the required potential to them. When these first and second spaced parallel strip-like electrodes are excited sequentially, the entire surface of the electroluminescent screen may be luminesced elementally, and further, when these sequential excitations are varied in magnitudes according to image forming signals, then a complete electro-optical image may be formed on the composite screen. This type of image forming electroluminescent screen had been disclosed by Piper in U. S. Patent No. 2,698,915, January 4, 1955. The objection to this type of image forming screen, however, is the difficulty of scanning, where,

either the first and second spaced parallel strip-like electrodes are excited sequentially by sluggish mechanical means, or an electronic computer arrangement, which becomes prohibitively complicated for practical uses. In order to obviate these difficulties, I had shown in my copending application Serial No. 434,157 filed June 3, 1954, now Patent No. 2,728,815, December 27, 1955, and Serial No. 481,174 filed January 11, 1955, now Patent No. 2,813,223, November 12, 1957, an arrangement of electroluminescent target which may be activated in elemental areas by a scanning electron beam. The present invention includes improvements of such an arrangement, a detailed specification of which is given in the following in connection with the accompanying drawings, wherein:

Fig. 1 is a longitudinal section of the color image tube, showing only essential parts, which includes the electroluminescent image target in cross-sectional view;

Fig. 2 is an exploded view of the color image target, including schematically the essential parts by which the video signals are applied to the target, and the direction in which the scanning beam forms a raster upon the image target;

Figs. 3 and 4 show diagrammatically different forms of adding barrier screens to the image target in accordance with the invention;

Fig. 5 illustrates diagrammatically modification of the combined barrier and collector screens which is suitable for use in operating one form of this invention;

Fig. 6 is a cross-sectional view of the barrier screen, showing its position with respect to the image target; and

Fig. 7 is a longitudinal diagrammatic view of the color image tube incorporating an electroluminescent color image forming target.

Fig. 1 illustrates the general layout of electroluminescent image formation, wherein, the screen comprises a translucent conductor electrode 2; a layer of electroluminescent phosphor material 1 placed over the flat surface of electrode 2; and a mosaic of mutually insulated conductor elements 3, 4, etc., placed over the phosphor material 1. Electrically, this screen structure forms a mosaic of capacitive elements, for example, elements 2 and 3 forming one independent capacitor, and elements 2 and 4 forming another independent capacitor, etc. Since as stated in the foregoing, that an electroluminescent screen may be referred to as a luminous capacitor, it is obvious therefore, that the screen just described may be referred to as a screen comprising a mosaic of luminous capacitors. The surfaces of elemental electrodes 3, 4, facing the primary electron beam, are made to produce secondary electrons upon impact by the primary beam, the latter of which is made to form a scanning raster upon the image target by conventional means, for example, by the deflection yoke, as shown diagrammatically in the drawing. A collector 5 of secondarily emitted electrons is included in the arrangement of Fig. 1. Functionally, when the beam-accelerating field is so adjusted that the ratio of secondary current to the primary current is greater than unity, the potential of bombarded electrode 3 may be raised positive substantially equal to the potential of collector anode 5, where an equilibrium state is reached, and the net secondary emission is then substantially unity. At this point, when the potential of electrode 2 is varied by the video signal through resistance R, the potential of electrode 3 will also vary through capacitive coupling, and effect corresponding change in secondary emission, thus varying the collector current. The effect therefore, is the same as if the electrode 2 were acting as the control grid; the electrode 3 as the cathode; and the collector 5 as the anode of an ordinary triode; causing the luminous capacitor to charge and discharge according to the applied video voltages. With the assumption that the thickness of dielectric sheet 1 is less

than the width of electrode 3, the transverse distribution of electric field between the electrodes 2 and 3 will be practically minimized, and the electroluminescence will be constrained within this region. As will be noted, when the beam is moved upon electrode 4, the electroluminescence will accordingly move to that region. Thus, when the screen is made of a mosaic of minute electrodes 3, 4, and a raster formed by the scanning beam, they will act as individual triodes, and produce the desired luminescence according to the applied image signals. When chromatic images are to be reproduced, the electrode 2 may be divided into three mutually insulated interleaved sections, each section aligned with a primary-color filter, and three separate video voltages representing different primary colors applied to these sections.

As stated in the foregoing, electroluminescence is effected by changing electric field across the luminous capacitor. To achieve this condition, I had shown in my above mentioned first patent application, now Patent No. 2,728,815, Dec. 27, 1955, an arrangement of high frequency carrier wave for the video signals, so that the electric field alternates several times across a luminous capacitor during impingement of the scanning beam upon it. In another arrangement, as shown in my above noted copending application (now patented as indicated by the above given number), the required charge and discharge of a luminous capacitor may be achieved by changing the polarity of the video signal by a phase inverting flip flop trigger circuit, which may be operated by the frame blanking signals in a television system. As an alternative, the dielectric sheet may be made slightly conductive to a value as to discharge the luminous capacitor during a frame or field period. Any of these systems for charging and discharging the luminous capacitors may be incorporated with the present invention, and accordingly further reference or drawing arrangement will not be repeated herein. The main object of the present invention, however, is a modification of the tube structure, which will be described in detail in the following specification.

Referring now to the exploded view of a color image forming electroluminescent screen in Fig. 2, a color filtering film 7 is first mounted over the inner surface of the face plate 6, which may serve as the end wall of the image tube, through which the image is viewed. The color filtering film contains a large number of very narrow color selective stripes, corresponding to suitable primary colors e. g., red (R), green (G), and blue (B). Next to each stripe, and aligned therewith, is translucent conductor strip 8. The conductor strips on stripes of each color are electrically connected to a corresponding resistor e. g., those on red stripes to resistor R1, those on blue stripes to resistor R2, and those on green stripes to resistor R3. Next over the conductor strips 8 is a sheet of thermoplastic dielectric matrix 9, dispersed with phosphorescent luminous cells. Finally, a mosaic of mutually insulated conductor elements 10 cover the dielectric sheet in the region to be scanned by the electron beam 11. In this arrangement, the resistors R1 to R3 are separately energized by primary-color video signals arriving from separate sources, as designated by the letters R, G and B. Thus, when the high velocity electron beam 11 strikes one or several of the elemental electrodes 10, the secondary emission establishes an electron path between these elemental electrodes and the electrode strips 8 through electron collector 12 and resistors R1 to R3, in the manner as described by way of the arrangement given in Fig. 1. When this arrangement is to be utilized for monochrome image reproduction, the three terminals for R1, R2 and R3 are electrically connected in parallel, terminating to a single resistor element, and monochrome image signals applied to it. Physically, however, the translucent strips 8 may be originally made into a single uniform sheet, and the color filtering film eliminated. Further, in reference to color image reproduction, the color filtering film may be eliminated, and the uniform electroluminescent phosphor film 9 may be divided into narrow stripes, aligned with the strips 8, and these stripes dispersed with electroluminescent phosphor cells having characteristics of luminescing in different primary colors, thus achieving similar results as if the color filtering film 7 were used. The elimination of the color filtering film 7 might be more desirable for practical purposes, as it absorbs an objectionable portion of the light emission from the luminescent film 9. These conditions, and also examples of phosphor materials that might be utilized with the screen, as shown, have been disclosed in my above mentioned copending applications (now patented as indicated above), and therefore, further specification is not necessary herein.

As suggested in my above mentioned first patent application, now Patent No. 2,728,815, Dec. 27, 1955, the mosaic elements 10, in Fig. 2, do not necessarily have to be metallic, or conductive. It has been shown in general practice that some insulating materials, for example, glass or plastics, have high secondarily emissive properties. Accordingly, the uniform surface of the plastic material utilized as retainer of the phosphor cells may as well replace the mosaic elements 10. In this case, the uniform surface of the plastic material, looking toward the primary electron beam, may be considered as a continuum of minute capacitor electrodes with respect to the strip electrodes 8. Thus, an elemental charge may be effected on this dielectric surface at a spot of primary beam impact with respect to a strip electrode 8. For practical purposes, the following conditions will satisfy: the secondarily emissive surface may be considered as the uniform surface of the dielectric material containing the phosphor cells; a secondary insulating material, having greater secondarily emissive properties, may be applied over the original dielectric sheet, for example, when the original dielectric is arranged with slight conductivity; or as an alternative, the electroluminescent material may be first applied on the base of strips 8, and secondarily emissive insulating material applied over, or, for example, thin sheet of mica or equivalents thereof, mounted over the electroluminescent material.

With the elimination of the mosaic elements 10, it is obvious that the screen construction becomes physically simple, and further modifications may be made without difficulty. For example, as suggested in my above mentioned copending application, Serial No. 481,174 filed Jan. 11, 1955, now Patent No. 2,813,223, Nov. 12, 1957, a barrier screen 19 may be utilized in conjunction with the image forming screen, as shown in Fig. 3, for the purpose of avoiding re-distribution of the secondarily emitted electrons over the emissive surface of the image forming target. In the case of eliminating the mosaic electrodes 10, the barrier screen grid may be directly placed over the uniform insulating surface of the image screen, such as shown in cross-sectional view in Fig. 6, wherein, 13, represents the secondarily emissive insulating surface of the electroluminescent phosphor screen 31, and 14 represents the barrier grid screen. It is obvious from this assembly that less care is needed in aligning the barrier screen over the insulating surface, than when the mosaic electrodes 10 were used; although particular alignment with respect to the strips 8 may be made, if so desired, according to the texture of the barrier grid, for example, it may be made of parallel wires; a screen with square or round openings; or of any other shape; and lastly, as an alternative, the screen may be applied upon the insulating emissive surface of 13 by known methods of electrodeposition, or equivalents thereof.

The function of the barrier grid has been described elsewhere in previous literature, but as a brief reminder, the drawing of Fig. 3 may be considered illustrative. Assuming that the velocity of the primary electron beam 15 is adjusted (by potential sources 16 and 17) to be high enough to cause secondary emission from the insulating surface of target 18 greater than unity, the net effect is to

charge it positively. Due to the negative potential upon barrier screen 19 (by potential 17) with respect to the accelerating wall 20, a retarding electric field is set up between the target 18 and the barrier screen 19, such that, those secondary electrons having low velocity are unable to pass through the screen opening, and accordingly return to the positive area of the target surface. Distribution of these low velocity secondary electrons to adjacent surface areas of the target is avoided by the fact that, the screen 19 is in close proximity with the emissive surface of target 18 (such as shown in cross-sectional view in Fig. 6), and the slow secondaries are constrained to return to the same surface area within a screen mesh spacing before escaping it. Secondary electrons having high velocity, however, pass through the screen openings and are further accelerated to the wall 20. As this secondary escapement from the screen 19 continues, the potential upon that particular surface area of the target 18 increases until it is substantially equal to the positive potential of accelerating wall 20, where an equilibrium state is reached and the net secondary current is substantially equal to the primary current. The overall condition is the same as described in the foregoing with reference to the illustrations of Figs. 1 and 2, but in this case, the inclusion of the barrier screen 19 avoids transverse distribution of elemental image luminescence upon the image forming screen, which otherwise could be effected by slow secondary electrons emitted from the emitting surface of the target 18, or 10 in Fig. 2.

In storage type of cathode ray tube, the inner wall is generally utilized as the collecting anode of secondarily emitted electrons. For the purpose utilized herein, however, the image forming target area is considered to be very large, such as for large screen television image reproduction. With such large target area, the distance from the geometric center of the target to the inner wall of the tube is considerably large, and it is possible that some escaping electrons from the target may fall back to a remote area upon the target. To avoid this condition, an auxiliary collector screen may be included in the tube, electrically connected to the main collector anode. This is schematically shown in Fig. 4, wherein, 21 is the primary electron beam; 22 is the secondarily emissive target; 23 is the barrier screen; and 24 is the auxiliary collector screen electrically connected to the main collector anode 25. In this case, the primary beam passes through the auxiliary collector screen 24 (some of the primary electrons being intercepted by this screen, but a major portion of it passing therethrough), and reaches the target 22 in the previously described manner. However, those secondary electrons released from the center portion of the target area find a shorter path to the screen 24, hence being attracted toward it, and those secondary electrons released from the edge of target area are (depending upon the distance between screen 24 and barrier grid 23) partly attracted by the screen 24 and partly by the wall 25, as shown by the dotted lines 26; thus further reducing the possibility of re-distribution effects.

An exploded diagrammatic view showing the respective relations of these added elements is given in Fig. 5, wherein, 27 is the secondarily emissive target; 28 is the barrier screen; and 29 is the auxiliary collector screen; the arrow 30 points the direction in which the primary electron beam travels. With regard to the foregoing description, the auxiliary collector screen 29 is desirable, but not necessarily essential, and its physical form is not critical, since its purpose is to aid the main electron collector in collecting all the necessary secondary electrons. For this reason, the screen 29 may have coarser mesh than the barrier screen 28, and it may also comprise few stretched wires; thus avoiding appreciable amount of primary beam interception by the screen 29.

Fig. 7 illustrates a cross-sectional diagrammatic view of the general appearance of the electroluminescent color image forming tube, wherein: 32 is the evacuated glass (or partly metal as the case may be) envelope enclosing an electron-emitting cathode 33, adjacent to which is included an intensity control electrode 34, followed by a beam-forming structure 35, which functions to concentrate the emitted electron stream 36 into a small scanning spot projected upon the secondarily emissive surface 37 of electroluminescent phosphor layer 38 which constitutes the image forming target, including the rows of metal strips 39 directly mounted upon the inner surface of the viewing face plate 40 by a method, for example, photodeposition, for convenience. Between the secondarily emissive surface (mounted at right angles to the axis of the electron beam 36) and the beam 36 there is disposed the barrier grid 41 closely adjacent to the surface 37. To complete the electron path of the secondarily emitted electrons from target surface, there is included a collector anode 42 which may act both as collector of these secondarily emitted electrons and accelerator of the primary beam 36, and to return the collected electrons to the emitter cathode 33 for the desired circulation of the primary beam. As shown cross-sectionally and schematically, every third of the translucent conductor strips 39 are electrically connected in groups, to which the video signals in different primary colors (red, green, blue) are applied for the desired combination of color image formation upon the electroluminescent screen (in different primary color stripes) 38. As indicated in the foregoing, the phosphor screen may be of a single color, for example, white color, and a striped color film included between the inner surface of the face plate 40 and the conductor strips 39. These variations, of course, depend upon the mode in which the image tube disclosed herein is utilized. Also, it had been indicated that the strips 39 could be all connected in parallel electrically for the production of monochrome images. It is thus obvious that the image tube described in the foregoing may be utilized for monochrome image formation; chromatic image formation; or according to the particular use, the chromatic image formation may be in two colors; three colors; or four colors without changing the characteristic operation of the tube, or the system associated therewith. The image tube illustrated in Fig. 7 is included with a beam deflection coil 43 which is of the conventional type utilized in monochrome television systems.

As has been experienced in the prior art, modifications and substitutions of parts in electronic devices of the type disclosed herein are possible without departing from the true spirit and scope of the invention, and accordingly, the foregoing should be construed only illustrative, and not in a limiting sense.

What I claim is:

1. An electroluminescent image forming device which comprises means for projecting a primary electron beam; a target of image forming elemental luminous capacitors in the path of said beam comprising a light-transparent electrode disposed plane-perpendicular with respect to the normal flow of said projected beam, an electroluminescent phosphor screen overlying upon said electrode, facing the beam, and an array of beam responsive elements over the surface area of said screen, facing the beam, each element adapted to produce secondary emission when struck by the primary beam, whereby forming elemental luminous capacitors, each capacitor comprising said light-transparent electrode, said screen, and one of said emissive elements; a collector anode for collecting the electrons of secondary emission from any one of said elements under impact by said beam, whereby forming elemental electrical paths between said beam responsive elements and the collector; and an output terminal means coupled to said light-transparent electrode for applying electrical video signals of various intensities between said terminal and the collector for individual excitation of said luminous capacitors in various intensities at points of primary impingement.

2. The device as set forth in claim 1, wherein, said light-transparent electrode is divided into a plurality of adjacently positioned light-transparent strip-like electrodes, and electrically connected in sequential steps into first, second and third sections; and wherein said phosphor screen comprises electroluminescent phosphors having the characteristics of exhibiting luminescence in first, second and third primary colors in stripe-like sections adjacently aligned with said strip-like sections; and first, second and third output terminal means coupled to said first, second and third sections, respectively, for applying first, second and third electrical video signals of various intensities between last named terminals and said collector for individual excitation of said luminous capacitors at points

of primary-beam impingement, whereby producing electroluminescence in different primary colors of various intensities, viewable from said first, second and third strip-like sections, at points of beam impingement upon said electron emissive elements.

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