May 14, 1957 B. KAZAN 2,792,447

ELECTROLUMINESCENT COLOR IMAGE REPRODUCTION

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Fig.1.

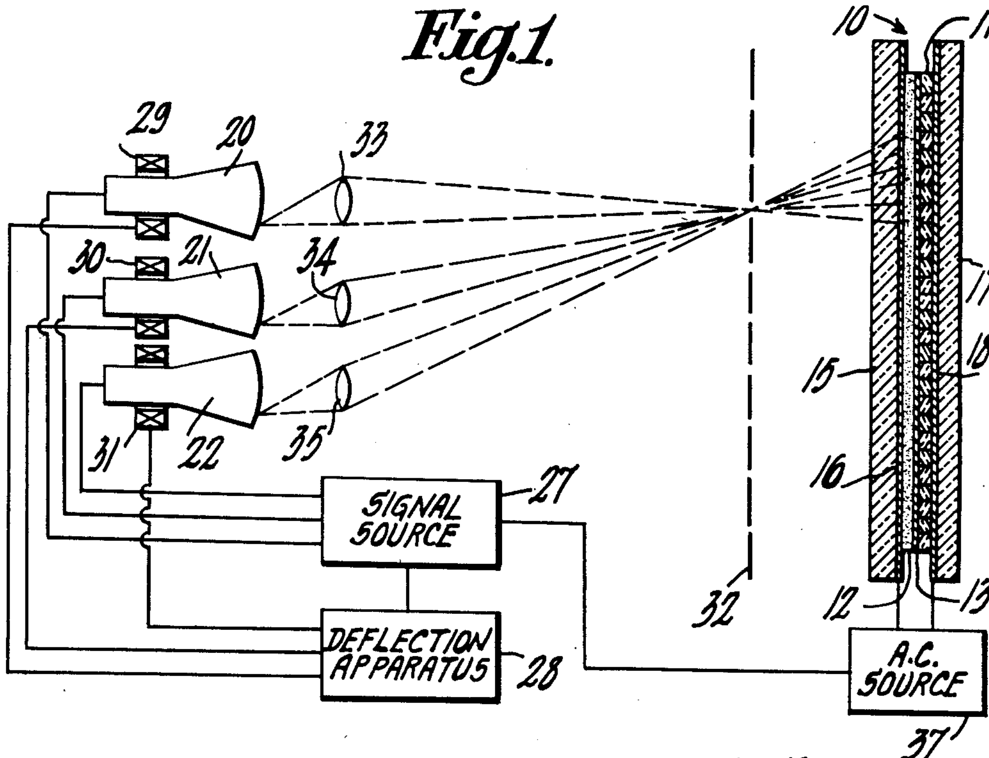

Fig.2.

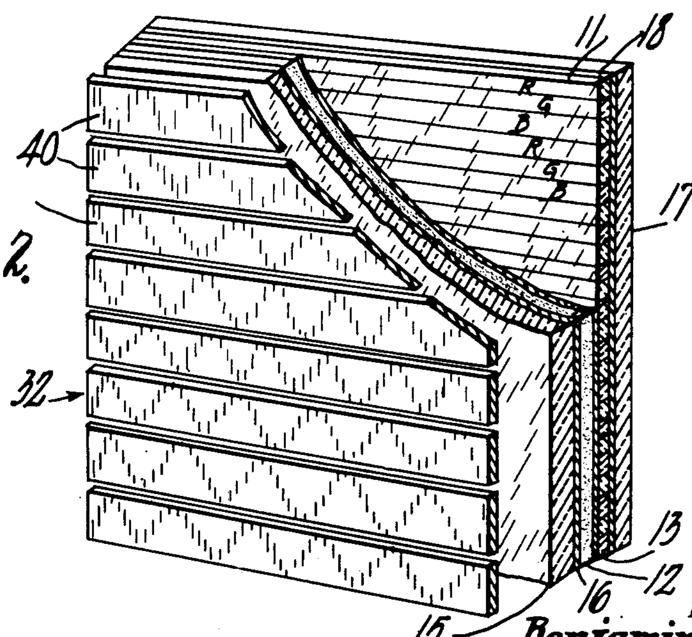

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Fig. 5.

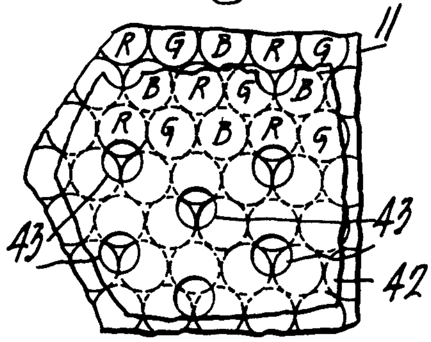


Fig. 3.

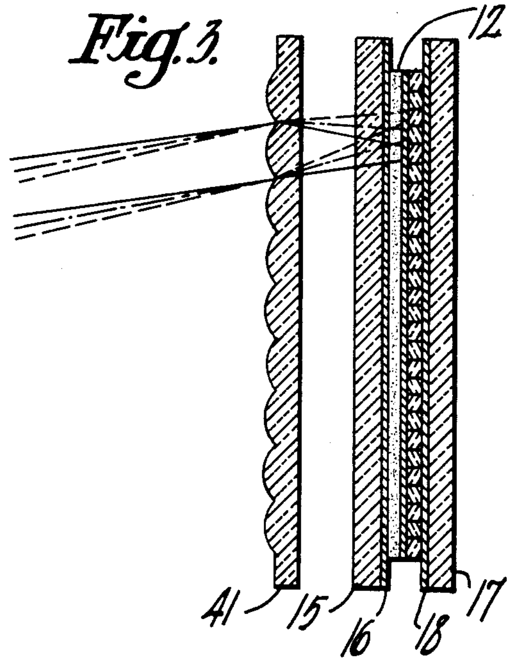
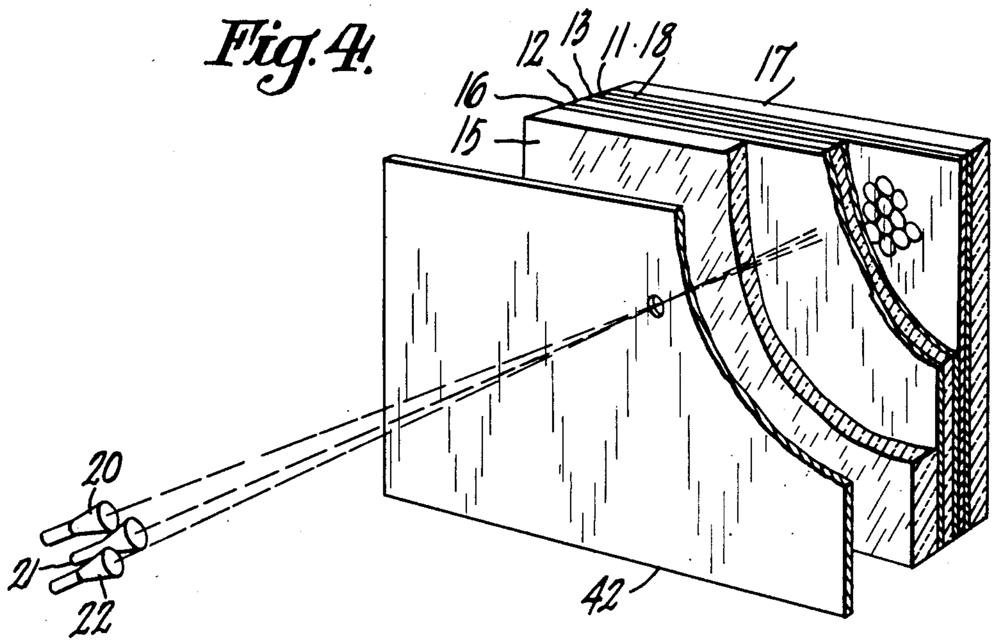


Fig. 4.



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ELECTROLUMINESCENT COLOR IMAGE REPRODUCTION

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Application April 21, 1955, Serial No. 502,963

4 Claims. (Cl. 178—5.4)

This invention relates generally to apparatus for reproducing light images and particularly to improved apparatus for converting electrical energy into light images by means of electroluminescent devices.

Large screen or projected color image reproducing devices have generally required the use of a plurality of projection tubes each adapted to provide an illuminating beam of radiation which may be a beam of visible light of a particular color. This required the use of illumination sources each providing a monochromatic beam through the use of optical filters or a selected phosphor source. Each of these systems is, of course, basically a system for converting electrical energy into radiant energy to provide a composite visual image in color.

One means for converting electrical energy into light energy utilizes the principle of electroluminescence, wherein a phosphor is excited by the application of a voltage or an electric field to the phosphor. Particles of a suitable phosphor may be embedded in a plastic and an electric field applied to the phosphor by conducting sheets placed in close association with the plastic.

An object of this invention is to provide an improved means for reproducing light images in natural or true color which utilizes the principle of electroluminescence.

Another object of this invention is to provide light image in full color of relatively large area from a modulated electrical signal while utilizing light sources each of which may provide ilumination of the same or uniform color composition and without the use of color filters.

In accordance with this invention, light images in natural color may be reproduced by varying the electrical field across elemental portions of a layer of electroluminescent material in accordance with a plurality of electrical signals by means of a photoconductive layer placed in close association with an electroluminescent layer. A plurality of individual beams of light or radiant energy, which are individually and separately modulated with the signal representative of the component color of an image, are developed in such a manner that only a beam representative of a given color component may irradiate those portions of the photoconductive layer associated with an electroluminescent material capable of producing the given color.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1 illustrates schematically one embodiment of the present invention for reproducing a light image in color wherein a plurality of flying spot scanners, each being amplitude or intensity modulated in accordance with signal information, are utilized to energize an electroluminescent device under the influence of a foraminous member or aperture mask;

Figure 2 shows a perspective view of a portion of the aperture mask and electroluminescent device of Figure 1 illustrating the relative positioning of the several elements;

Figure 3 is a side elevation view of an electroluminescent device and lens system or array provided in accordance with the present invention;

Figure 4 is a perspective view of a further arrangement for reproducing a televised image in natural color in accordance with the present invention; and

Figure 5 is a schematic showing of an electroluminescent target and beam interceptor of opaque material having a plurality of openings or apertures therein.

Referring now to the drawings and particularly to Figure 1, there is shown electroluminescent device **10** adapted, when properly energized, to reproduce a color image. One form of the electroluminescent device suitable for use in the practice of this invention comprises a sandwich type of construction including a luminescent layer **11** and a photoconductive layer **12** separated by and contiguous with an opaque or semiopaque layer **13**. More specifically, the sandwich includes on one side a transparent base member **15** which may be glass, having deposited thereon a transparent conductive layer or coating **16**. On the other side, there is employed a similar glass base member **17** also coated on its inside surface with a transparent conductive layer or coating **18**. The luminescent layer **11** and photoconductive layer **12** are sandwiched between the base members **15** and **17** and are in contact with each other and the conductive layers **16** and **18**.

In order to enable the reproduction of a color image, the electroluminescent layer **11** is divided, in one way or another into elemental regions each of which is smaller than a picture element. The individual regions are arranged in a desired sequence and each produces a particular color of electroluminescent light. The desired elemental regions may be a parallel line arrangement, as illustrated in Figure 2, and may be obtained by dividing the electroluminescent phosphors into elemental regions each having an appropriate color response.

For example, the repeating series of elemental regions R, B and G, shown in Figure 2 for a three color system, may be silver activated zinc sulfide for blue, manganese activated alpha wellemite for red, and chromium activated aluminum berylliate for green.

In preparing the luminescent layer or sheet, the particles of phosphor material are mixed with or embedded in a light transmitting insulating material, i. e. a plastic, lacquer, wax or the like.

According to one method of preparing the luminescent body, a unit quantity of a plastic matrix material for the phosphor was prepared with the following ingredients in approximately the given quantities:

	Grams
Ethyl cellulose	1.2
Iso-amyl alcohol	16.5
Amyl acetate	25.5
Acetone	14.5
Di-octyl phthalate	1.5
Octyl acetate	1.0

This mixture was blended with approximately two grams of finely divided phosphor particles, for example, copper activated zinc sulfide particles having a diameter of the order of one to five microns. The mixture of plastic and phosphor was then ball milled for approximately one hour. Finally, the milled preparation was sprayed into a suitable base plate. In an electroluminescent panel actually built, the thickness of this layer was of the order of 1 to 3 mils.

The photoconductive layer 12 may be made of any photoconductive material sensitive to the type of radiation to be employed in activating the layer, and may be made in a manner similar to that described above for the luminescent layer. The radiation may be visible light, ultra-violet, infra-red, or X-ray radiation or particles of radiation such as that produced by radio-active materials.

The photoconductive material may comprise particles of a host crystal selected from the group consisting of selenides, sulphides, and sulpho-selenides of cadmium having incorporated therein activator proportions of a halide and activator proportions of a metal selected from the group consisting of copper and silver, said particles being adapted to make low resistance contact to one another in the presence of incident radiation in the range between 4000 A. and 9000 A. A photoconductive body may then comprise a mass of this photoconducting powder with or without a binder.

One method for producing a photoconducting powder comprises recrystallizing a material selected from the group consisting of sulphides, selenides and sulpho-selenides of cadmium to a desired range of particle sizes, incorporating into the recrystallized material activator proportions of a halide and activator proportions of a metal selected from the group consisting of copper and silver. By carefully controlling the firing process, the surfaces of the particles of said recrystallized material make low resistance electrical contact to one another in the presence of incident radiation in the range between 4000 A. and 9000 A. By providing such low resistance electrical contact between particles, the photosensitivity of the particles is unmasked, facilitating the flow of photocurrents through a body of the powder.

The photoconductive layer may have a thickness comparable to that of the luminescent layer. The relative thickness of these layers is determined by the types of materials involved and the desired voltage drop across each layer when the electroluminescent device is in the unenergized condition.

The conductive layers 16 and 18 may one or both, be constituted of metal plates, grids, meshes or sheets or films of material adapted to be transparent to the type of radiation to be employed in operation of the electroluminescent device. One method of forming these layers is to apply transparent conductive material to the base plates 15, 17 having the desired radiation transmitting qualities. The transparent conductive material may be of the type formed by deposition of the vapors of stannic chloride, water and methanol.

An additional opaque or semiopaque layer 13 may be interposed between the photoconductive layer 12 and the electroluminescent layer 11 to limit the amount of light feedback to the photoconductive layer 12 from the electroluminescent layer 11. Such a layer may be of a density to allow enough light to pass to utilize regenerative action. However, where the device is to be used for reproducing varying light images, this layer should be sufficiently opaque to preclude any possibility of enough light being fed back to result in self energization. In operation, the elemental areas of the photoconductive layer 12 become conductive in accordance with the intensity of the incident radiation on each of the elemental areas. As a result of the increased conductivity of the photoconductive elements, the corresponding elemental areas of the electroluminescent layer have voltage increments applied across them. The increased voltage across the electroluminescent areas causes corresponding increases in output light. Since the electroluminescent device is comparatively thin, light emitted from a given area of the electroluminescent layer represents radiation striking the corresponding area of the photoconductive layer.

It is, of course, to be understood that the particular electroluminescent device illustrated is but one form applicable to the system of the present invention. Other devices having a layer of phosphor material comprising elemental areas subdivided in a particular manner for increased efficiency or sensitivity may be utilized. In a device having an elementally divided phosphor material it is required that the color elements of the electroluminescent material be accurately registered with the elements of photoconductive material in order to selectively energize the subelemental color areas.

A plurality of flying spot scanners, which may be, for example, cathode-ray tubes 20, 21 and 22, are used to energize selected areas in accordance with the color information communicated by each tube. Three tubes are shown to illustrate the use of the present arrangement in a three color system; however, two or more tubes may be utilized in accordance with the present invention with an appropriate luminescent device depending on the color system employed for signal transmission. Suitable operating potentials may be applied to each of the cathode-ray tubes 20, 21 and 22.

Signal information necessary to modulate the beam intensity of each of the tubes 20, 21 and 22 may be supplied from a signal source 27 such as a conventional color television signal receiver or signal generator adapted to derive signal information representing the individual primary color information concerning a televised object. The signal source 27, may supply synchronizing pulses to a deflection apparatus 28, which in turn supplies the yokes 29, 30 and 31 with deflection currents for purposes of deflecting the electron beams in the cathode-ray tubes 20, 21 and 22 in synchronism with each other and in synchronism with the transmitted information.

Interposed between the electroluminescent device 10 and the cathode-ray tubes 20, 21 and 22 is a foraminous beam intercepting structure or mask 32 which is so arranged that the irradiating beam from any one cathode-ray tube may reach only definite lines or points of the electroluminescent device 10 which will reproduce the particular color in accordance with the signal representations with which the particular beam is modulated.

The beam or flying spot produced by each of the cathode-ray tubes may be optically focused on the apertures of the slotted or foraminous mask 32 by means of individual lens systems shown diagrammatically at 33, 34 and 35.

Voltage from source 37 is applied across the electroluminescent device 10 by means of the conducting layers previously described.

In operation, the embodiment of Figure 1 provides an output image on the side of the electroluminescent device 10 opposite from the photoconductive layer 12 on which the flying spots are focused. The flying spots energize elemental areas of the photoconductive layer 12 which reduces the impedance across elemental areas of the photoconductive layer 12 so that an increased voltage is applied across elemental areas of the electroluminescent layer 11. Since the incident radiant energy is modulated in accordance with signal information, and since the variation of the impedance of the elemental areas of the photoconductive layer 12 varies with a variation in illumination, the amount of electroluminescent light emitted from each elemental area is determined by the modulation of the cathode-ray tubes 20, 21 and 22. In this manner, a color image is elementally reproduced by the electroluminescent device 10.

In general, electroluminescent layers energized by an alternating voltage produce two maxima of light during each A.-C. cycle rather than continuous light. As an unmodulated flying spot from a cathode-ray tube scans the device with an A.-C. voltage applied to the device, the electroluminescent light will vary periodically at twice the A.-C. frequency. As a result, if signals are used for intensity modulating the incident radiation and assuming a photoconductive material having a very fast response characteristic, the A.-C. frequency must be at least half as high as the highest signal frequency employed. Also, the A.-C. frequency must be sufficiently high relative to the speed of the flying spot so that the electroluminescent light will not appear in the form of a sequence of dots or dashes.

However, photoconductive materials presently known generally have a decay time greater than one microsecond. It is therefore not required that the A.-C. signal voltage be synchronized with the scanning information. Synchronization would be required if the decay time of the photoconductive phosphor were less than the time of one cycle of the A.-C. voltage in order to insure emission of electroluminescent light at the moment of excitation of the photoconductor.

The details of the mask **32** and the electroluminescent device **10** may be more readily seen from an examination of Figure 2. The mask **32** comprises a plurality of opaque members **40** which are separated by a plurality of apertures in the form of line openings or slits which are positioned with respect to the regularly recurring subelemental portions of the electroluminescent layer **11** so as to allow the illuminating beam from a single one of the plurality of beam sources or cathode-ray tubes to approach the device **10** from a particular direction and therefore to illuminate a particular one of the red, green or blue strips. It is to be noted, however, that the illumination provided by any one of the beams does not impinge directly upon the corresponding strip in the electroluminescent layer, but, instead is caused to impinge upon the associated portion of the photoconductive layer.

As above discussed, the beam falling upon the photoconductive layer is effective in reducing the impedance of that portion of the layer thereby providing a larger percentage of the source voltage across the selected region of the electroluminescent layer.

It is also within the purview of the present invention to utilize a lens in place of the mask **32** as shown in Figure 3.

The lens may be of the plano-convex variety as illustrated or may be of any suitable lenticular type adapted to provide an optical arrangement for directing the illumination from a plurality of sources to impinge upon selected portions of photoconductive layer **12**.

It is, of course, to be understood that the geometry of the entire system must be selected to provide the desired intersection of the beams or illumination at only the appropriate areas of the device **10**. That is, in the use of a mask, as illustrated in Figure 1, the source to mask distance must be related to the mask to electroluminescent device distance in such a manner to effect illumination of only one of the color reproducing areas by one of the beams.

This is also true when utilizing an optical device or lens **41** as shown in Figure 3. The lens spacing from both the device **10** and the source of illumination must be such as to allow a concentration and an impingement of a particular beam upon a portion of the photoconductive layer **12** which is adjacent to a strip of electroluminescent material adapted to produce the particular color representative of the signal information with which the particular beam is modulated. It is also to be understood that the line type structure illustrated in Figures 1, 2 and 3 may be of either the horizontal line type or the vertical line type depending on the particular system utilized.

In Figure 4, there is shown an arrangement wherein the source of illumination such as the cathode-ray tubes **20**, **21** and **22** are placed in a triangular arrangement at a particular distance from an aperture mask **42** having therein a plurality of circular apertures adapted to allow the passage of the beam from a particular one of the sources of illumination which is directed toward a portion of the photoconductive layer **12** which is adjacent to an elemental area of electroluminescent material selected

to provide light of the particular color desired. In Figure **4**, only one of the apertures is illustrated for the purpose of simplicity, however, in Figure 5 there is shown a cut-away portion of the aperture mask **42** having therein a plurality of circular apertures positioned above a cut-away portion of the electroluminescent layer **11** to illustrate the registration of the mask **42** with the corresponding areas of the electroluminescent device **10**.

It may be seen from the examination of Figure 5 that the geometry of the mask **42** and of the electroluminescent device **10** is such as to provide illumination of only one red, green or blue area of the electroluminescent layer **11**. With this type of construction, it is necessary to provide a plurality of recurring subelemental color areas in two directions. This may be accomplished as illustrated by the use of circular dot areas repeating in color sequence in a predetermined order as determined by the color system utilized. For example, the color system illustrated utilizes three sources of illumination and three primary colors for the reproduction of a color image. It is therefore necessary to provide triads of color dots regularly recurring in two directions throughout the area of electroluminescent layer **11**.

It may be further noted that it may be desirable to provide an aperture diameter which is somewhat less than the diameter of the corresponding subelemental color areas. This will reduce the problem of precise registration of each of the plurality of of beams with the sub-elemental color areas. Accordingly, a small misregistration will still allow the entire beam to impinge upon a portion of the photoconductive layer **12** which is associated with only the particular color desired.

Light images in natural color may accordingly be reproduced by elemental controlling of the electric field across a layer of electroluminescent material in accordance with a plurality of electrical signals, by utilizing a plurality of individual beams to selectively control the impedance of elemental regions of a photoconductive layer placed in close association with an electroluminescent layer. Each of the beams may be individually and separately modulated with signals represenative of the component colors of a televised image and may be developed and controlled through synchronized scanning and the use of a foraminous member or optical device to irradiate only those portions of the photoconductive layer associated with the electroluminescent material capable of producing the given color.

Having thus described the present invention, what is claimed is:

1. Apparatus for reproducing light images in color in accordance with a color signal containing information representative of a plurality of color components derived by scanning a subject and synchronizing information pertaining to said scanning comprising, in combination: a source of said color signal; means for deriving from said color signal separate component color signals respectively representative of each of said plurality of color components, a plurality of sources of illumination of the cathode-ray type for producing substantially point sources of illumination, said sources of illumination having a fixed predetermined spatial relationship with respect to each other; a plurality of signal-responsive means each respectively connected with a different one of said sources of illumination for changing the intensity of said illumination in response to an applied signal, means coupling a different one of said separate component color signals respectively to a different one of said signal-responsive means, scanning deflection means connected with each of said sources of illumination for causing each of said point-sources of illumination to scan a raster, synchronizing means receiving said synchronizing information connected with said scanning deflection means to synchronize the deflection of each of said point-sources of illumination with the scanning of said subject; optical means coupled to said sources of illumination for achieving optical registry of

said rasters at the focal plane of said optical means, a light-sensitive color-image-producing target positioned in the optical path of said sources of illumination, said target comprising a layer of protoconductive material and a layer of electroluminescent material in close operative relationship: a source of alternating current; means coupling said alternating-current source across said two layers in series relation to produce an electric field across said target; said target being positioned such that said photoconductive layer lies in said focal plane whereby said photoconductive layer intercepts illumination from each of said point sources, said electroluminescent layer comprising a plurality of light-emitting phosphor deposits arranged in separate geometrical patterns, the number of deposits in each pattern corresponding to the number of said plurality of color components, each deposit in a given pattern being responsive to energy conditionally directed upon it from a given one of said illumination sources to produce a different color of light emission corresponding respectively to the color represented by a different one of said color component signals; and an illumination-source selection means interposed between said sources of illumination and said target to direct illumination from the source of illumination associated with each of said component color signals only onto the area of the photoconductive layer adjacent to the phosphor deposits in each pattern having light emission of the corresponding color.

2. Apparatus for reproducing light images in color in accordance with a color signal containing information representative of a plurality of color components derived by scanning a subject and synchronizing information pertaining to said scanning comprising, in combination: a source of said color signal; means for deriving from said color signal separate component color signals respectively representative of each of said plurality of color components, a plurality of sources of illumination of the cathode-ray type for producing substantially point sources of illumination, said sources of illumination having a fixed predetermined spatial relationship with respect to each other; a plurality of signal-responsive means each respectively connected with a different one of said sources of illumination for changing the intensity of said illumination in response to an applied signal, means coupling a different one of said separate component color signals respectively to a different one of said signal-responsive means, scanning deflection means connected with each of said sources of illumination for causing each of said point-sources of illumination to scan a raster, synchronizing means receiving said synchronizing information connected with said scanning deflection means to synchronize the deflection of each of said point-sources of illumination with the scanning of said subject; optical means coupled to said sources of illumination for achieving optical registry of said rasters at the focal plane of said optical means, a light-sensitive color-image-producing target positioned in the optical path of said sources of illumination, said target comprising a layer of photo-conductive material and a layer of electroluminescent material in close operative relationship; a source of alternating current; means coupling said alternating-current source across said two layers in series relation to produce an electric field across said target; said target being positioned such that said photoconductive layer lies in said focal plane whereby said photoconductive layer intercepts illumination from each of said point sources, said electroluminescent layer comprising a plurality of light-emitting phophor deposits arranged in separate geometrical patterns, the number of deposits in each pattern corresponding to the number of said plurality of color components, each deposit in a given pattern being responsive to energy conditionally directed upon it from a given one of said illumination sources to produce a different color of light emission corresponding respectively to the color represented by a different one of said color component signals; said phosphor deposits being in the form of strips, each of said patterns comprising successive strips of different color light-emitting phosphor deposits in a predetermined order and arranged in parallel relationship with respect to one another; and an illumination-source selection means interposed between said sources of illumination and said target to direct illumination from the source of illumination associated with each of said component color signals only onto the area of the photoconductive layer adjacent to the phosphor deposits in each pattern having light emission of the corresponding color, said selection means comprising a thin plate having apertures spaced proportionally to the width of said patterns, said apertures being shaped to restrict the light emanating from each separate illumination source to the areas of said photoconductive layer associated with the separate corresponding color light-emitting phosphor deposit strips.

3. Apparatus for reproducing light-images in color in accordance with a color signal containing information representative of a plurality of color components derived by scanning a subject and synchronizing information pertaining to said scanning comprising, in combination: a source of said color signal; means for deriving from said color signal separate component color signals respectively representative of each of said plurality of color components, a plurality of sources of illumination of the cathode-ray type for producing substantially point-sources of illumination, said sources of illumination having a fixed predetermined spatial relationship with respect to each other; a plurality of signal-responsive means each respectively connected with a different one of said sources of illumination for changing the intensity of said illumination in response to an applied signal, means coupling a different one of said separate component color signals respectively to a different one of said signal-responsive means, scanning deflection means connected with each of said sources of illumination for causing each of said point-sources of illumination to scan a raster, synchronizing means receiving said synchronizing information connected with said scanning deflection means to synchronize the deflection of each of said point-sources of illumination with the scanning of said subject; optical means coupled to said sources of illumination for achieving optical registry of said rasters at the focal plane of said optical means, a light-sensitive color-image-producing target positioned in the optical path of said sources of illumination, said target comprising a layer of photoconductive material and a layer of electroluminescent material in close operative relationship; a source of alternating current; means coupling said alternating-current source across said two layers in series relation to produce an electric field across said target; said target being positioned such that said photoconductive layer lies in said focal plane whereby said photoconductive layer intercepts illumination from each of said point sources, said electroluminescent layer comprising a plurality of light-emitting phosphor deposits arranged in separate geometrical patterns, the number of deposits in each pattern corresponding to the number of said plurality of color components, each deposit in a given pattern being responsive to energy conditionally directed upon it from a given one of said illumination sources to produce a different color of light emission corresponding respectively to the color represented by a different one of said color component signals; said phosphor deposits being in the form of strips, each of said patterns comprising successive strips of different color light-emitting phosphor deposits in a predetermined order and arraged in parallel relationship with respect to one another; and an illumination-source selection means interposed between said sources of illumination and said target to direct illumination from the source of illumination associated with each of said component color signals only onto the area of the photoconductive layer adjacent to the phosphor deposits in each pattern having light emission of the corresponding color, said selection means

comprising a plurality of lenses interposed in said optical path, said lenses being of the type having a cylindrical surface and having a width proportional to said pattern-width and a length substantially equal to the length of said strips, said cylindrical surface having the proper curvature to produce the correct refraction of the illumination from said illumination sources to direct the illumination from each separate illumination source onto corresponding color light-emitting phosphor deposit strips.

4. Apparatus for reproducing light images in color in accordance with a color signal containing information representative of a plurality of color components derived by scanning a subject and synchronizing information pertaining to said scanning comprising, in combination: a source of said color signal; means for deriving from said color signal separate component color signals respectively representative of each of said plurality of color components, a plurality of sources of illumination of the cathode-ray type for producing substantially point sources of illumination, said sources of illumination having a fixed predetermined spatial relationship with respect to each other; a plurality of signal-responsive means each respectively connected with a different one of said sources of illumination for changing the intensity of said illumination in response to an applied signal, means coupling a different one of said separate component color signals respectively to a different one of said signal-responsive means, scanning deflection means connected with each of said sources of illumination for causing each of said point-sources of illumination to scan a raster, synchronizing means receiving said synchronizing information connected with said scanning deflection means to synchronize the deflection of each of said point-sources of illumination with the scanning of said subject; optical means coupled to said sources of illumination for achieving optical registry of said rasters at the focal plane of said optical means, a light-sensitive color-image-producing target positioned in the optical path of said sources of illumination, said target comprising a layer of photoconductive material and a layer of electroluminescent material in close operative relationship; a source of alternating current; means coupling said alternating-current source across said two layers in series relation to produce an electric field across said target; said target being positioned such that said photoconductive layer lies in said focal plane whereby said photoconductive layer intercepts illumination from each of said point sources, said electroluminescent layer comprising a plurality of light-emitting phosphor dot deposits arranged in separate geometrical patterns, the number of deposits in each pattern corresponding to the number of said plurality of color components, each deposit in a given pattern being responsive to energy conditionally directed upon it from a given one of said illumination sources to produce a different color of light emission corresponding respectively to the color represented by a different one of said color component signals, each of said geometrical patterns being an elemental area of said electroluminescent layer and each phosphor deposit being of a size substantially of the same order as the point of light projected from said source of illumination as it strikes the photoconductive layer, said dot deposits arranged within said patterns in a color sequence of a predetermined order; and an illumination-source selection means interposed between said sources of illumination and said target to direct illumination from the source of illumination associated with each of said component color signals only onto the area of the photoconductive layer adjacent to the phosphor deposits in each pattern having light emission of the corresponding color.

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