

Dec. 20, 1960

E. E. LOEBNER
IMAGE DISPLAY

2,965,802

Filed Nov. 27, 1956

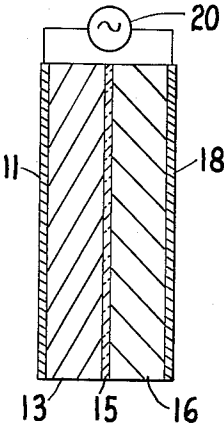


FIG. 1.

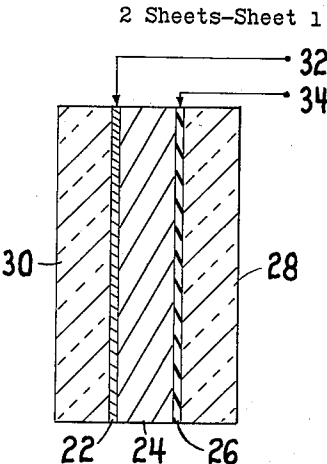


FIG. 2.

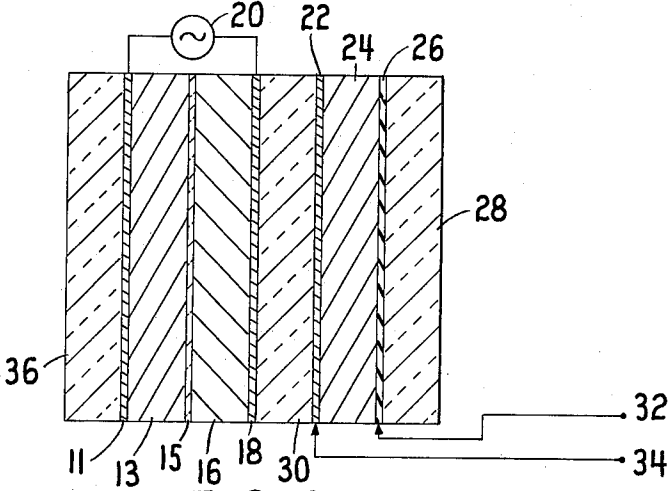


FIG. 3

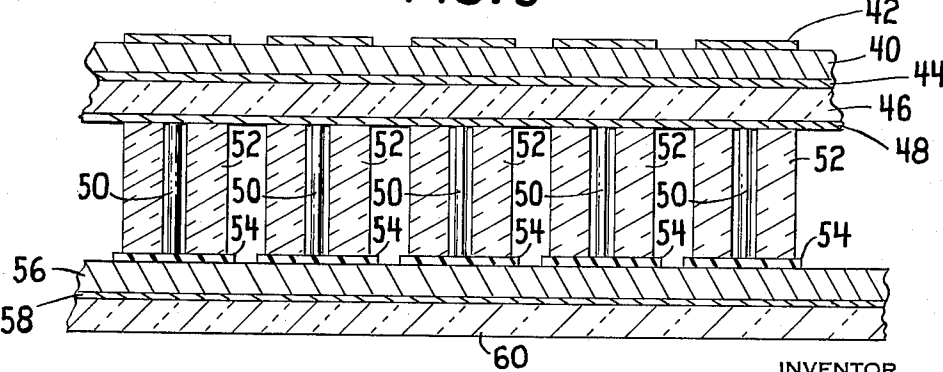


FIG. 4.

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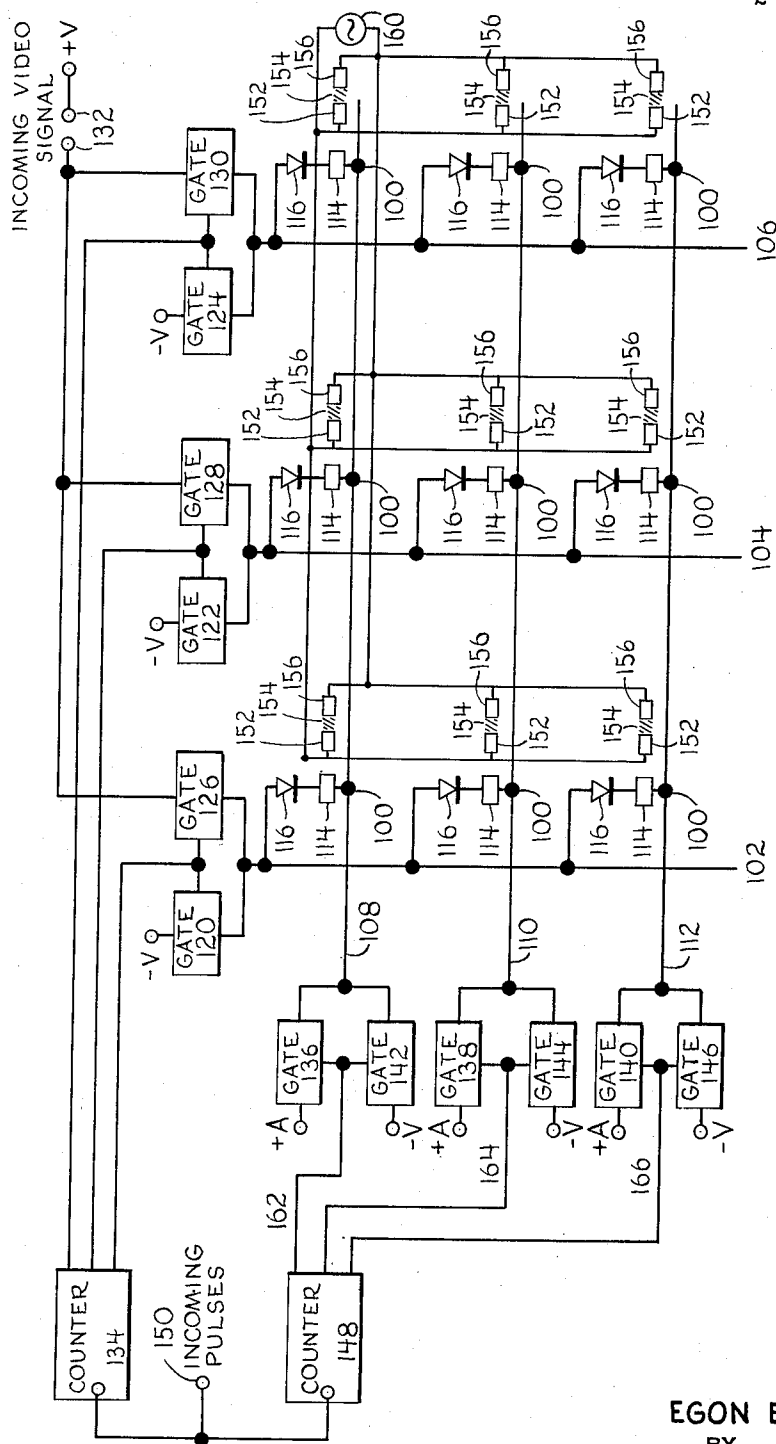
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2 Sheets-Sheet 2



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1

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IMAGE DISPLAY

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4 Claims. (Cl. 315-169)

This invention relates to image display devices and more particularly to an image display device of the flat type comprising a plurality of structurally similar discrete image elements.

Prior art teaches the concept of energizing electroluminescent phosphors through the use of a cross conductor mesh arrangement whereby the electroluminescent material in a given image area may be energized by a video voltage so as to produce video modulated light. Though such structures show commercial promise, it is apparent that improvement of the light output or efficiency of the electroluminescent layer is necessary in such displays. When a screen of electroluminescent material is combined with a sweep system which contemplates very brief intervals of video excitation, the resulting light output values, as yet, are not comparable to those produced by present day cathode ray tube screens.

This invention contemplates increasing available average light output from an electroluminescent image screen by providing a time period of light emission greater than the time period of video signal excitation of any given elemental image area. This is accomplished by a concept making it possible to take advantage of the relatively long time period available between successive energizations of any given elemental image area.

Thus, it is an object of this invention to provide available increased light output from an electroluminescent display.

It is a further object of this invention to utilize the light output characteristics of electroluminescent materials to increase available total light output of an image display.

It is also an object of this invention to provide peak available light output from each elemental area of an electroluminescent display which is monotonically related to a characteristic of the exciting signal voltage.

Briefly, in one aspect of the invention I provide a flat image display element comprising a plurality of layers having one layer for producing light related to the amplitude and time duration of a signal voltage and a second layer excited by the light output from said first layer for producing light having an available peak intensity monotonically related to the light output of said first layer for a time duration, longer than the original signal voltage duration.

For a better understanding of the invention, together with other and further objects and capabilities thereof, reference is made to the following description and appended claims in connection with:

Fig. 1 showing the viewing layer of the image display element of an embodiment; and

Fig. 2 showing the video signal excited layer of the image element of an embodiment; and

Fig. 3 showing the elements of Fig. 1 and Fig. 2 in combination;

2

Fig. 4 showing a plurality of image elements in specific embodiments; and

Fig. 5 is a scanning system useful with the image display device of the preceding figures.

In Fig. 1 there is shown a cross section of a display image element comprising what might be termed an elemental sandwich of layers having a transparent conductive layer 11, an electroluminescent layer 13, a semi-light-absorbing layer or filter 15, which may be conductive, a photoconductive layer 16 and a second transparent conductive coating 18. Alternating current exciting source 20, which may be in the megacycle range, is shown connected between the transparent conductive layers 11 and 18.

When the surface 18 of the element shown in Fig. 1 is exposed to a source of radiant energy selected preferably from the visible or near visible portion of the light spectrum, there is a decrease in the impedance of photoconductive layer 16. Thus, there is an increase in the voltage impressed across electroluminescent layer 13. If the light emitted from electroluminescent layer 13 is in the spectral range as to also decrease the resistance of photoconductive layer 16, it can be seen that the complete unit operates somewhat similar to a unstable trigger device in that light feeding back through the filter layer 15 tends to further decrease the resistance of photoconductive layer 16 and thus further increase the amplitude of the excitation voltage applied to electroluminescent layer 13. This regenerative action continues even after removal of the radiant energy excitation of surface 18 and quickly drives the unit further toward a given light output at a rate and toward a peak output primarily governed by the intensity of the original exciting light passing through surface 18 to photoconductive layer 16 and partly controlled by the intensity of the light fed back through filter layer 15. By selecting the light absorbing characteristics of filter 15 so as to limit the amount of light fed back from electroluminescent layer 13, it is possible to limit the time period of the unstable condition to a period somewhat less than the maximum period between successive energizations of an image element in known television systems. Thus, after the external source of radiant energy is removed the intensity of the light output from layer 13 continues to increase to a peak value related to the peak intensity of the externally applied radiant energy and then starts to decrease. At this point the resistance of the photoconductive layer 16 starts to increase, thereby decreasing the voltage across the electroluminescent layer 13. This in turn decreases the amount of light fed back to the photoconductive layer 16 and as a result, the element returns to the stable condition where no light is being emitted from layer 13.

The decay rate, after external radiant energy excitation is removed, depends not only upon the filter characteristics of light absorbing layer 15, but also upon the photoconductive characteristics of layer 16. For example, by selecting a photoconductive material for layer 16 which responds relatively rapidly to radiation in the spectral band of the external radiating source and somewhat slower to radiation in the spectral band of the light emitted by the electroluminescent layer 13, it is possible to make the resistance of the photoconductive material decrease rapidly when excited by light from the external source and then increase relatively slowly after the external source is extinguished.

Thus, it can be seen that the element shown in Fig. 1 is stable in the extinguished condition until temporarily excited by external radiant energy whereupon it assumes an unstable condition during which it emits light and slowly returns to its stable extinguished condition. So

long as the maximum value of the external light source is not such as to allow saturation of photoconductive layer 16, an increase in the amount of instantaneous light from the external source will accelerate the rate at which the resistance of the photoconductive layer decreases; however, the rate at which the resistance of the photoconductive layer returns to the extinguished condition value remains essentially independent of variations in exciting source amplitude and duration.

As can be seen, the unit of Fig. 1 provides means for producing light having a peak intensity monotonically related to the peak intensity of an exciting light source.

In Fig. 2 I have shown an electroluminescent exciting element comprising a transparent conductive layer 22, supported by transparent panel 30, an electroluminescent layer 24 and a second conductive layer 26 supported by panel 28. Layer 26 and panel 28 may or may not be transparent. A video voltage, not shown, is coupled between the two terminals 32 and 34 which are connected to the two conductive layers 22 and 26, respectively, so as to establish an exciting field across electroluminescent layer 24 which is proportional to the video information received for the image element in question. Though not shown, additional pulse voltages may be necessary to bring the electroluminescent material up to the light incipient state as more fully explained in copending application Serial Number 306,909, filed August 28, 1952, by Norman L. Harvey. Thus, light output from the element portion shown in Fig. 2 is directly related to the video information supplied to the image element in question, being energized during only those brief intervals when the video signal carries information necessary to the image element.

Present day black and white television uses a sweep system wherein an image element is briefly energized each $\frac{1}{30}$ of a second. When such a signal is applied to the electroluminescent element in Fig. 2 the time average light output of the element may be too low for direct viewing but yet sufficient to excite the structure of Fig. 1.

In Fig. 3 I have shown the structures of Fig. 1 and Fig. 2 combined as a complete image element, primarily using the same reference numerals as used in Fig. 1 and Fig. 2. Thus the complete element is seen to comprise the support layer 28, conductive layer 26, electroluminescent layer 24, transparent conductive layer 22, transparent support layer 30, transparent conductive coating layers 18 and 11, and electroluminescent layer 13 separated from photoconductive layer 16 by filter layer 15 which may be conductive. If desired, a further transparent supporting layer 36 may be used.

Operation of the complete element shown in Fig. 3 is based upon operation of the portion shown in Fig. 1 and Fig. 2. The video signal applied to terminals 32 and 34 excites electroluminescent layer 24 to produce a light output which is related to the amplitude of the video signal. The light from layer 24 passes through transparent conductive coating 22, transparent layer 30 and transparent conducting coating 18 to impinge upon photoconductive layer 16. The resistance of photoconductive layer 16 thus decreases, increasing the voltage across electroluminescent layer 13, supplied by exciting voltage source 20. Light is thereupon emitted by layer 13 through transparent layers 11 and 36 in the viewing direction and also through filter layer 15 in the feed-back direction. As was brought out in connection with operation of the element portion shown in Fig. 1, the light fed back through filter 15 further decreases the resistance of photoconductive layer 16 which in turn allows a greater portion of the voltage supplied from exciting source 20 to be applied across electroluminescent layer 13. This regenerative action continues at a rate primarily governed by the intensity of the exciting light emanating from layer 24.

When the video voltage is removed from terminals 32 and 34 light is no longer produced in the exciting layer 24, and the resistance of the photoconductive layer 16

starts to increase, thereby decreasing the voltage across electroluminescent layer 13. As a result, light output from layer 13 starts to decay at a rate governed in part by the filter characteristics of layer 15 and the sensitivity of photoconductive layer 16 to the light fed back. Thus it can be seen that the unit of Fig. 3 provides means for producing a light output having a peak intensity related to the peak amplitude of a video signal voltage. Also, it should be clear that the light output of the viewing layer 13 is monotonically related to the light output of exciting layer 24.

In Fig. 4 there is shown a preferred embodiment of a portion of a specific image display screen which has been constructed. The screen comprises a structure having elemental areas basically similar to the structure of Fig. 3 in that it is composed of layers including an electroluminescent exciting layer 40 sandwiched between a conductive layer 42 and a transparent conductive layer 44. Conductive layers 42 and 44, as shown in Fig. 4 may each comprise a plurality of parallel conductors in the form of a grid wherein the conductors of one of the grids, e.g., grid 42, are arrayed vertically and the conductors of the other grid, e.g., grid 44, are arrayed horizontally in parallel planes. Thus, by energizing any given horizontal-vertical conductor pair, it is possible to establish a field across a discrete portion of layer 40 so as to cause this portion of the layer to luminesce. Considering this small portion of layer 40 as an image element it can be seen that energization of a large number of such horizontal-vertical conductor pairs in a given sweep sequence will provide an equally large number of image elements and form a complete image display. For a more complete disclosure of cross-grid structures reference is made to the copending applications Serial Number 306,909, filed August 28, 1952, by Norman L. Harvey, and Serial Number 306,800, filed August 22, 1951, now abandoned, by William K. Squires, both of which are assigned to the assignee of this application.

In the structure of Fig. 4, layer 46 may be a transparent supporting layer. Immediately adjacent supporting layer 46 there is provided a transparent conductive layer 48. For each horizontal-vertical conductor pair the photoconductive layer comprises a cadmium sulphide or other suitable crystal 50 supported in a light conducting tube 52, which may be of Lucite, having a rough internal surface and a smooth external surface. It has been found advisable to coat the external surface of tubes 52 with a light opaque film so as to make the tubes impervious to the passage of light horizontally between tubes. In order to connect the photoconductive cadmium sulphide crystals 50 to the conductive filter layer 54, I have also found it useful to depend upon a minute dot of silver paint or some other conductive paint. Electroluminescent viewing layer 56, transparent conductive layer 58 and the transparent supporting layer 60 complete the structure. An appropriate alternating voltage source, similar to source 2D in Fig. 3, may be connected between layers 48 and 58, for excitation.

Operation of the elements in Fig. 4 is similar to the operation of the element in Fig. 3. When the video voltage is applied across any horizontal-vertical conductor pair in layers 42 and 44, the interjacent portion of electroluminescent layer 40 luminesces to provide a relatively low intensity light which passes through layers 44, 46 and 48 to impinge upon the associated cadmium photoconductive crystals 50 and decreases its resistance. In view of the voltage impressed between transparent conductive layers 48 and 58, it can be seen that there is a shift in voltage distribution and a larger portion of the voltage begins to be impressed across the associated portion of the electroluminescent viewing layer 56. Light fed-back from layer 56 as filtered by layer 54 further decreases the resistance of the pertinent cadmium crystal in regenerative manner. Then as the video information is removed from across the particular portion of layer 40 in ques-

tion, light output from the associated image element in layer 56 starts its decay toward the stable non-excited condition. As was the case in connection with Fig. 3 the decay period is governed in part by the filter characteristics of layer 54 and the sensitivity of the photoconductive layer 50 to the light fed back. It is to be noted that the delay must be restricted to a time period which is less than the period existing between successive energizations of the image element in question.

Through most complete displays require far more image elements than shown in Fig. 4, it should now be clear that structures built in accordance with this invention have image elements with increased total time average light output relative to the image elements of electroluminescent screens which rely solely upon light output from a brief video excitation period. The advantages of my concept do not depend upon the type of scanning utilized in that any scanning structure or system may be used which is found suitable for energizing the electroluminescent exciting layer. Further, even though improvements are made in methods of extracting light from known electroluminescent material and even though more efficient electroluminescent material may be discovered in the future, it is believed that my concept makes it possible to obtain substantially maximum light output possible from any given material.

Though the concept is not to be limited to any single means or method of scanning an electroluminescent exciting layer, there is shown, in Fig. 5, one scanning system believed to be suitable. This particular scanning system is more exhaustively disclosed and claimed in a copending application filed by Donald C. Livingston and assigned to the assignee of this application, now United States Patent 2,774,813, issued December 18, 1956.

Referring to Fig. 5, which is a schematic representation, it can be seen that there is provided a plurality of grid cross-over points 100 which are fed from a plurality of parallel separate vertical conductors 102, 104 and 106, forming the first grid array of the electroluminescent exciting layer.

The second grid array of the electroluminescent exciting layer comprises a plurality of parallel separate horizontal conductors 108, 110 and 112. Each cross-over point 100 is coupled to a separate image element portion of the electroluminescent exciting layer 114. Each of the electroluminescent exciting layer image elements 114 is coupled to a vertical conductor through a rectifier 116. Each of the vertical conductors 102, 104 and 106 is connected through an associated normally open gate circuit 120, 122 and 124 to a source of negative potential, indicated as $-V$. Each of the vertical conductors is also connected through an associated normally closed gate 126, 128 and 130 to a source of positive potential, shown as $+V$, in series with an incoming video signal connected across terminals 132. Counter 134 has a separate output for each vertical conductor associated gate pair, i.e., gate pair 120—126, gate pair 122—128 and gate pair 124—130.

Horizontal conductors 108, 110 and 112 are each coupled through an associated normally open gate 136, 138 and 140 to a source of positive potential shown as $+A$. Also, each of the horizontal conductors is coupled through an associated normally closed gate 142, 144 and 146 to a source of negative potential shown as $-V$. Counter circuit 148 supplies a separate output for each horizontal conductor associated gate pair 136—142, 138—144 and 140—146. Both counters 134 and 148 are supplied with synchronizing pulses from terminal 150. Since counter circuits and gate circuits are so well known to the art, it is not believed necessary either to give a detailed description of the internal circuitry of each block or show the common terminals necessary for incoming pulse development and pulse transmittal from the counters to the associated gate circuits.

Each electroluminescent exciting layer image element

114 is associated with a photoconductive image element 152, a filter element 154 and an electroluminescent final display element 156. The exciting voltage for the elements 154—156 are supplied from a source 160.

The potential of the source shown as $+A$ is chosen so as to have a value relative to an arbitrary reference level, which exceeds the sum of the potentials from source $+V$ and the maximum potential of the video signal impressed across terminals 132. The potential $-V$ assists in back biasing rectifiers 116 to prevent improper conduction.

Operation of the circuit may be understood by considering a video signal which includes a synchronizing pulse for each line of the video information. The video signal is applied across terminals 132 and the stripped synchronizing pulses, separated by a circuit not shown, are applied at terminal 150. For each synchronizing pulse impressed on the input of counter 32, the output provides a series of pulses or pulse train having one pulse for each vertical conductor in the complete image display. The first output pulse of counter 134 simultaneously opens gate 126 and closes gate 120. At the same time counter 148 is triggered into supplying a pulse to close gate 136 and open gate 142. The counter 148 differs from counter 134 in that counter 148 supplies one pulse for each incoming sync pulse with the first output pulse appearing on lead 162 and the second output pulse on lead 164 and the third output pulse appearing on lead 166 and so on depending upon the number of horizontal conductors utilized in the complete display. Thus the first sync pulse, in opening gates 126 and 142 and in closing gates 120 and 136, allows the incoming video signal to be impressed on the first electroluminescent image element 114 at the upper left hand corner of the display, as shown. After the normal excitation period of the one image element, counter 134 impresses a pulse between gates 122 and 128 while terminating the pulse fed to gates 120 and 126. When gate 128 is opened the incoming signal is then applied to the second electroluminescent video element 114 for the period of the pulse supplied by counter 134. After a period of time equal to the normal image element excitation period, counter 134 supplies a pulse opening gate 130 and closing gate 124 and terminates the pulse between gates 122 and 128. Gates 122 and 128 then return to their normal position, i.e., gate 122 is open and gate 128 is closed.

Considering that the structure shown in Fig. 5 should be expanded to include the number of image elements desired in each given display line, it can be seen that counter 134 supplies pulses which effectively allows the incoming video signal to sweep horizontally across line 108. When the last image element in line 108 is extinguished, the next pulse at terminal 150 trips counter 148 to terminate its output pulse on line 162 and supply an output pulse to 164 and the sequence is repeated.

As each electroluminescent image element 114 in the exciting layer is energized by the incoming video signal, its associated photoconductive element 152 is excited in accordance with the intensity of light so produced by the element 114. As explained in connection with Fig. 4, the resistance of the photoconductive element 152 therefore decreases allowing the greater share of the voltage supplied from source 160 to be impressed across the electroluminescent element 156. Electroluminescent element 156 starts to luminesce feeding back light through filter 154 in regenerative fashion. As a result electroluminescent image element 156 in the viewing layer is driven toward a high light output having a peak intensity related to the amplitude of the video signal exciting the associated element 114. Though successive elements 114 are swept with video information as previously described, element 156 may be allowed to luminesce for a period substantially longer than the excitation period of the associated element 114. The decay rate of any overall image element need be no faster than the period between suc-

cessive scans of a given element. As a result there is an increased total time average light output relative to the total time average light output of the exciting layer 114, which is limited by the brief video excitation signal period.

While there has been shown and described what is at present considered the preferred embodiment of the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the invention as defined by the appended claims.

Having thus described the invention, I claim:

1. An element in an image display comprising the combination of a plurality of closely adjacent layers having an electroluminescent exciting layer, a source of video information voltage signals coupled to excite said electroluminescent exciting layer for producing light output varying substantially in accordance with the video information of said voltage signals, a layer of light sensitive material having impedance characteristics varying in accordance with variations in intensity of light impinged thereon, said light sensitive layer being light coupled to said electroluminescent exciting layer, an electroluminescent viewing layer electrically and light coupled to said light sensitive layer, and a voltage source coupled across said electroluminescent viewing layer and said light sensitive layer.

2. An element in an image display comprising the combination of a plurality of closely adjacent layers having an electroluminescent exciting layer, a source of video information voltage signals coupled to excite said electroluminescent exciting layer for producing light output varying substantially in accordance with the video information of said voltage signals, a layer of light sensitive material having impedance characteristics varying in accordance with variations in intensity of light impinged thereon, said light sensitive layer being light coupled to said electroluminescent exciting layer, an electroluminescent viewing layer, a light filter layer for electrically coupling and light coupling said light sensitive layer to said electroluminescent viewing layer, and a voltage source coupled across said electroluminescent viewing layer and said light sensitive layer.

3. An image display element of the type made up of

a plurality of contiguous layers comprising the combination of an electroluminescent exciting layer, a source of video information signals coupled to excite said exciting layer to produce light output therefrom related to the video information contained in said signals, an electroluminescent viewing layer, a layer of light sensitive material having an electrical impedance characteristic varying substantially in accordance with variations in intensity of light impinged thereon; said light sensitive layer being light coupled to said exciting layer and being electrically and light coupled to said viewing layer, the attenuation in the light coupling between the light sensitive layer and the viewing layer being different than the attenuation in the light coupling between the light sensitive layer and the exciting layer, and a source of voltage coupled between the viewing layer and the light sensitive layer.

4. In an image display the combination comprising a plurality of individual signal responsive first electroluminescent transducer means for producing a light output related to the video information contained in a signal, a video signal source, means coupled to said video signal source of sweeping said plurality of transducer means with said video signal, a viewing screen comprising a plurality of second electroluminescent transducer means for producing light output related to the amplitude of an exciting signal, a power source, a plurality of photosensitive means having light modulatable impedance characteristics, means for electrically coupling each of said photosensitive means between said power source and a separate one of said second transducer means, and means for light coupling each of said photosensitive means to a separate one of said first signal responsive transducers.

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