Sept. 2, 1969 TADAO KOHASHI 3,465,202

ELECTROLUMINESCENT DEVICE FOR DERIVING A BRIGHT OUTPUT IMAGE FROM A DARK INPUT IMAGE

Filed Oct. 17, 1966 2 Sheets-Sheet 1

FIG. 1

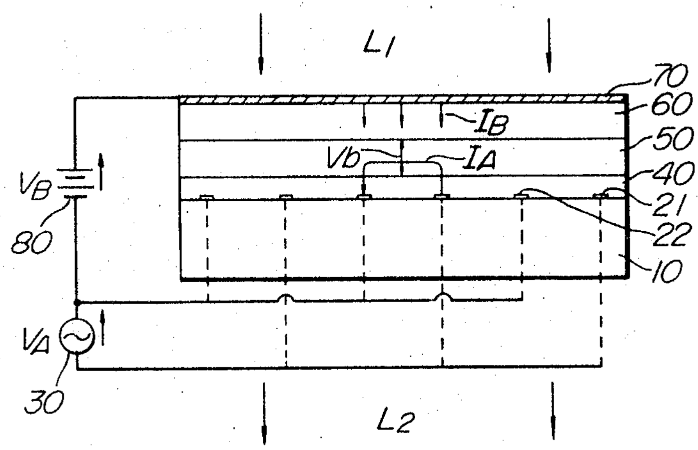


FIG. 2

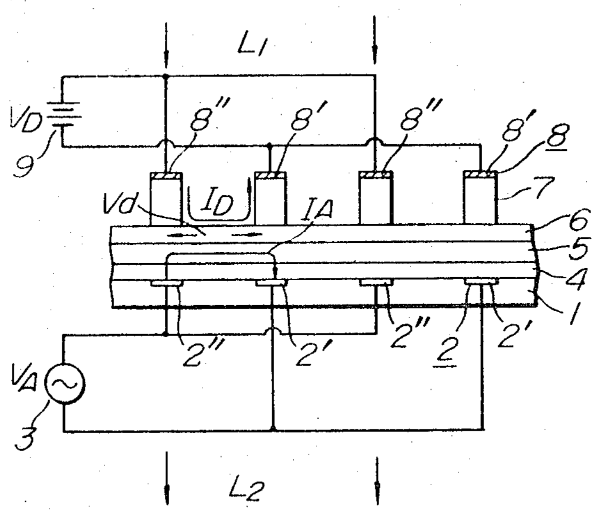


FIG. 3

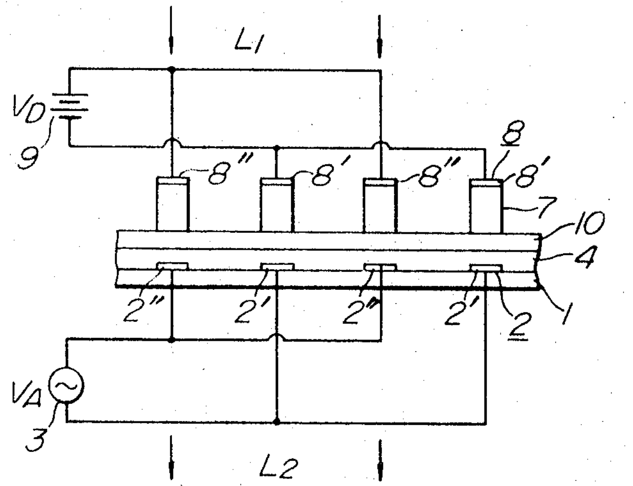


FIG. 4

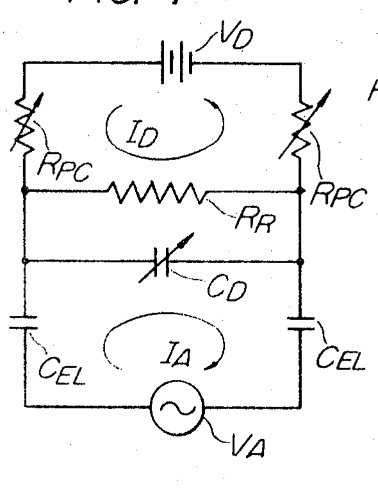
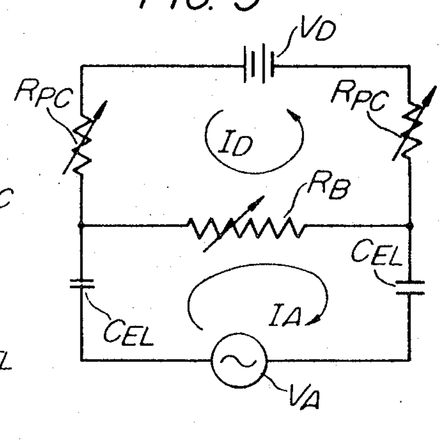


FIG. 5



United States Patent Office

3,465,202

Patented Sept. 2, 1969

3,465,202

ELECTROLUMINESCENT DEVICE FOR DERIVING A BRIGHT OUTPUT IMAGE FROM A DARK INPUT IMAGE

Tadao Kohashi, Yokohama, Japan, assignor to Matsushita Electric Industrial Co., Ltd., Osaka, Japan, a Japanese corporation

Filed Oct. 17, 1966, Ser. No. 587,227
Claims priority, application Japan, Oct. 25, 1965, 40/65,856
Int. Cl. H05b *37/02, 39/04, 41/14*
U.S. Cl. 315—169 19 Claims

ABSTRACT OF THE DISCLOSURE

An electroluminescent device for deriving a bright output image from a dark input image comprising an electroluminescent layer, a non-linear impedance layer and means for applying a biasing electric field across said non-linear impedance element, wherein a current flowing through said electroluminescent element is caused to flow in the lengthwise direction thereof depending upon the variation in the impedance of said impedance element.

This invention relates to improvements in electrically luminescent devices of the kind, for example, in which the luminescence of electroluminescent elements is controlled by use of a non-linear impedance element. This invention further relates to improvements in electrically luminescent devices of the kinds, for example, in which the luminescence of electroluminescent elements is controlled by an alternating current by utilization of the dielectric amplification function of a non-linear ferroelectric element in a layer form.

Several proposals have heretofore been made as to devices of the kind described above. According to the principle on which these prior devices have been based, an AC voltage and a DC voltage are applied in superposed relation to a stack consisting of a ferroelectric non-linear element in a layer form and an electroluminescent element in a direction of its thickness, and a bias voltage (polarization) in a direction of thickness of the non-linear ferroelectric element is controlled to vary the dielectric amplification action of the non-linear ferroelectric element in the direction of its thickness for thereby controlling the luminescence of the electroluminescent element. In order that the electroluminescence device having the luminescence control system based on such principle can operate at a high sensitivity, it is required that the capacitance of the electroluminescent layer in the direction of its thickness be substantially comparable to that of the non-linear ferroelectric layer in the direction of its thickness. However, the non-linear ferroelectric layer commonly composed of $BaTiO_3$ ceramics (Pb, Zr)TiO_3 ceramics or the like has a very high specific dielectric constant of the order of 1000 to 3000, whereas the electroluminescent layer composed of dispersed intrinsic electroluminescent material or the like has a low specific dielectric constant of the order of 10 to 20. Accordingly, the non-linear ferroelectric layer must have a thickness more than 100 times that of the electroluminescent layer in order to satisfy the aforementioned conditions. In view of the fact that the maximum thickness of the electroluminescent layer is limited to 30 to 50 microns according to the present manufacturing technique, the non-linear ferroelectric layer is required to have an extremely large thickness of the order of 3 to 5 millimeters. On the other hand, in order to effectively control the luminescence of the electroluminescent layer by the dielectric amplification action, the DC bias voltage in the direction of thick-

ness of the non-linear ferroelectric layer must be in the order of 10 kilovolts per centimeter or higher. Therefore with the prior structure having therein a thick ferroelectric layer, control of a high DC voltage of the order of several to ten kilovolts becomes necessary. For the above reason, electroluminescence devices based on the above principle including a stack of a non-linear ferroelectric layers and an electroluminescent layer are extremely difficult to make and it is the present status that such devices are hardly put into practical use.

It is therefore the primary object of the present invention to provide an electroluminescence device which is based on an entirely new principle and is quite free from the prior defects as described above.

According to one aspect of the invention, there is provided an electroluminescence device based on a principle according to which a biasing electric field for the lateral component of a layer-form non-linear impedance element is unidirectionally controlled to thereby control the luminescence of an electroluminescent element. According to another aspect of the invention, there is provided an electroluminescence device based on a principle according to which a biasing electric field (that is, polarization) for the vertical component of a layer-form non-linear ferroelectric element is controlled to thereby control the dielectric amplification action of the lateral component, and this dielectric amplification action of the lateral component is utilized to control the luminescence of an electroluminescent layer in an AC fashion.

The above and other objects, advantages and features of the present invention will become apparent from the following description with reference to the accompanying drawings, in which:

FIG. 1 is a schematic sectional view of one embodiment of the electroluminescence device of the invention, the device being shown together with a power supply system therefor;

FIGS. 2 and 3 are schematic sectional views of other embodiments of the invention shown together with power supply systems therefor; and

FIGS. 4 and 5 are equivalent circuit diagrams of the embodiments shown in FIGS. 2 and 3, respectively.

Referring to FIG. 1, there is shown an electroluminescence device embodying the invention which is adapted to invert and amplify an input image L_1 in the form of light rays, radiant rays and so on to thereby derive a negative optical output image or inverted optical output image L_2 from an electroluminescent element.

The electroluminescence device includes a support base **10** of, for example, transparent glass having a high specific resistance and a high resistance to voltage and a plurality of light-transmissive electrodes **21** and **22** of material such as stannic oxide disposed on the support base **10** in suitably spaced relation from each other. The electrodes **21** and **22** constitute two sets of alternately arranged and electrically insulated electrode groups, and a source of AC power supply **30** having a zero or extremely low output resistance is connected between these electrode groups to supply an AC voltage V_A thereacross. The electroluminescence device further includes an electroluminescent element **40** formed of an electroluminescent layer of a powdery phosphor such as ZnS:Cu, Al blended and molded with a suitable binder; a non-linear ferroelectric capacitance element **50** formed of a layer or panel of material such as $BaTiO_3$ ceramics or (Pb, Zr) TiO_3 ceramics; a photoconductive layer **60** formed by blending and molding a powdered photoconductive material having a high dark resistance such as Cas:Cu, Cl with a binder having a high specific resistance such as an epoxy resin; and an electrode **70** which permits transmission of an input light image L_1. The electrode **70** is made from a light-transmissive material such as stannic oxide when used with an input image L_1 in the form of light rays and made from a vacuum deposition film or thin plate of metal such as aluminium or a layer of conductive paint when used with an input image L_1 in the form of radiant rays such as X-rays. A source of DC power supply **80** is connected between the electrode **70** and an output terminal of the AC power supply **30** to apply a DC voltage V_B across the device.

Suppose now that the AC voltage V_A is applied across the electrodes **21** and **22**. Then, since the specific dielectric constant of the non-linear ferroelectric element layer **50** is more than 100 times that of the electroluminescent element layer **40**, a large alternating current I_A flows in the lateral direction bypassing the ferroelectric element layer **50** and flows into the spaced electrodes **21** and **22**. In the invention, the thickness of the electroluminescent element layer **40** interposed between the electrodes **21**, **22** and the ferroelectric element layer **50** is made extremely thin or in the order of, for example, 30 microns; each of the electrodes **21** and **22** has a narrow width of, for example, about 200 microns; the spacing between the adjacent electrodes **21** and **22** is made more than about twice the thickness of the electroluminescent element layer **40** or in the order of, for example, 500 microns; and the AC voltage V_A is selected at a suitable value so that the electroluminescent element layer **40** may not luminesce by the lateral electric field established across the electrodes **21** and **22** by the AC voltage V_A. Under such an arrangement, the bypassing alternating current I_A running in the lateral direction or in the direction parallel to the face of the non-linear ferroelectric element layer **50** establishes a strong electric field in the direction of thickness of the thin electroluminescent element layer **40** lying between the electrodes **21**, **22** and the ferroelectric element layer **50**, and luminescence developed at this portion gives a bright optical output L_2.

When under this state the DC voltage V_B is applied across the device and an input image L_1 is projected onto the electrode **70** as shown in FIG. 1, the DC resistance in the direction of thickness of the photoconductive layer **60** decreases by the photoconductive effect. As a result, a DC photo-current I_B flows between the electrode **70** and the electrodes **21**, **22** to increase the DC bias voltage (hence, biasing electric field) Vb applied in the direction of thickness of the non-linear ferroelectric element layer **50**. The above increase in the DC bias voltage Vb results in reduction of the specific dielectric constant of the non-linear capacitance element layer **50**, and resultant reduction in the lateral dielectric amplification leads to decrease of the laterally bypassing alternating current I_A. Thus, the luminous output makes an abrupt decrease with the increase in the image input L_1, and a bright, inverted, negative output image L_2 can be obtained when the input image L_1 is applied in the form of extremely dark light rays.

Effective control on such DC bias voltage in the direction of thickness of the non-linear ferroelectric element layer **50** can be accomplished by suitably selecting the DC resistance of the non-linear ferroelectric element layer **50** so that it is suitably smaller than the dark resistance of the photoconductive layer **60** and by suitably selecting the DC resistance of the electroluminescent element layer **40** so that it is suitably smaller than the DC resistance of the non-linear ferroelectric element layer **50** whereby the DC bias voltage can be effectively applied to the element layer **50**. For the highly sensitive operation of the device which is so arranged that the luminescence of the electroluminescent element is controlled by the lateral dielectric amplification action in the manner as described above, it is necessary to select in such a way, for example, that the geometrical mean of the maximum capacitance and the minimum capacitance of the non-linear ferroelectric element layer **50** variable depending on the DC bias voltage is substantially equal to the capacitance of the luminous portion of the electroluminescent element layer **40**.

With the prior system, the thickness of the non-linear ferroelectric layer must be made more than 100 times the thickness of the electroluminescent layer in order to have substantially equal capacitances for both the layers. In contrast thereto it is utterly unnecessary in the electroluminescent device of the invention to have such a thick layer of non-linear ferroelectric element because the dielectric amplification action in the lateral direction thereof, that is, in the direction parallel to the face thereof is utilized as illustrated. More precisely, in FIG. 1, an effective AC circuit related with the AC voltage V_A is provided by a series circuit of the capacitances in the direction of thickness of those portions which contribute to the luminescence of the electroluminescent element layer **40** between the electrodes **21**, **22** and the non-linear ferroelectric element layer **50** and the capacitance of the non-linear ferroelectric element layer **50** in the lateral direction thereof.

The capacitance of the non-linear ferroelectric element layer **50** in the lateral direction thereof can be made smaller by reducing the thickness of the layer to an extent that it is substantially equal to the above capacitance of the electroluminescent element layer **40**. For example, in the present embodiment, the thickness of the element layer **50** can be made extremely thin or in the order of several tens to 100 microns by employing the aforementioned material. Of course, the spacing between the adjacent electrodes **21** and **22** may be varied to suitably adjust the capacitance in the lateral direction of the element layer **50**. Since moreover the DC bias voltage Vb is applied in the direction of thickness, the ferroelectric element layer **50** in this embodiment can be made extremely thin even if a maximum value of the DC bias voltage Vb of the order of, for example, 10 kilovolts per centimeter is requested. Therefore a voltage value of several tens to 100 volts will suffice to obtain a strong electric field, and it will be apparent that this system is by far excellent compared with the prior system. By the above feature, the DC voltage V_B of extremely low value suffices, and since the value of the requested bias voltage Vb is so low, the thickness of the photoconductive layer **60** can be made extremely thin or in the order of several tens to 100 microns. This thin thickness of the photoconductive layer **60** ensures excitation by the input image L_1 to the sufficiently deep interior of the layer and makes possible to attain a high-sensitivity operation. Furthermore, as apparent from FIG. 1, the photoconductive layer **60** is isolated from the AC circuit and is arranged to make a DC operation so as to utilize a great variation in its DC resistance. By virtue of the above arrangement, this layer can operate at a very high sensitivity. Still further, by selecting the AC voltage V_A at a high frequency for thereby obtaining a lateral AC amplification as high as 1000 times the common value, the electroluminescent device can now be used as a high-amplification image device and the like.

Referring to FIG. 2, there is shown another embodiment of the invention which is also adapted to invert and amplify an input image L_1 in the form of light rays, radiant rays and so on to thereby derive a negative optical output image or inverted optical output image L_2 from an electroluminescent element.

The electroluminescent device includes a support base **1** of, for example, transparent glass having a high specific resistance and a high resistance to voltage and a plurality of light-transmissive electrodes **2** of material such as tin oxide disposed on the support base **1** in suitably spaced relation from each other. The electrodes **2** constitute two sets of alternately arranged and electrically insulated electrode groups **2′** and **2″**, and a source of AC power supply **3** having a zero or extremely low output resistance is connected between these electrode groups to supply an AC voltage V_A thereacross. The electroluminescence device further includes an electroluminescent element 4 formed of an electroluminescent layer of a powdery phosphor such as ZnS:Cu, Al blended and molded with a suitable binder; a nonlinear ferroelectric capacitance element 5 formed of a layer or panel of material such as $BaTiO_3$ ceramics or (Pb, Zr)TiO_3 ceramics; a resistance layer 6 which is made opaque so as to avoid feedback of the emission from the electroluminescent layer 4 to the input side; and photoconductive elements 7 of material such as CdS:Cu, Cl having a high dark resistance. The photoconductive elements 7 are disposed at positions directly opposite to the electrodes 2.

An electrode 8 having the property of transmitting the input light rays is provided on the top of each photoconductive element 7, and all the electrodes 8 constitute two sets of electrically insulated electrode groups 8′ and 8″ corresponding to the electrode groups 2′ and 2″. The electrode 8 is made from a light-transmissive material such as tin oxide when used with an input image L_1 in the form of light rays and made from a vacuum deposition film or thin plate of metal such as aluminum or a layer of conductive paint when used with an input image L_1 in the form of radiant rays such as X-rays. A source of DC power supply 9 is connected between these electrode groups 8′ and 8″ to apply a DC voltage V_D thereacross.

Suppose now that the AC voltage V_A is applied across the electrodes 2′ and 2″ as shown in FIG. 2. Then, since the specific dielectric constant of the ferroelectric nonlinear capacitance element layer 5 is more than 100 times that of the electroluminescent element layer 4 as described in the previous embodiment, a large alternating current I_A flows in the lateral direction bypassing the ferroelectric element layer 5 and flows into the spaced electrodes 2′ and 2″. In the invention, the thickness of the electroluminescent element layer 4 interposed between the electrodes 2′, 2″ and the ferroelectric element layer 5 is made extremely thin or in the order of, for example, 30 microns; each of the electrodes 2′ and 2″ has a narrow width of, for example, about 200 microns; the spacing between the adjacent electrodes 2′ and 2″ is made more than twice the thickness of the electroluminescent element layer 4 or in the order of, for example, 500 microns; and the AC voltage V_A is selected at a suitable value so that the electroluminescent element layer 4 may not luminesce by the lateral electric field established across the electrodes 2′ and 2″ by the AC voltage V_A. Under such an arrangement, the bypassing alternating current I_A running in the lateral direction or in the direction parallel to the face of the non-linear ferroelectric element layer 5 establishes a strong electric field in the direction of thickness of the thin electroluminescent element layer 4 lying between the electrodes 2′, 2″ and the ferroelectric element layer 5, and luminescence developed at this portion gives a bright optical output L_2.

When under this state the DC voltage V_B is applied across the electrodes 8′ and 8″ and an input image L_1 is projected onto the electrodes 8 as shown in FIG. 2, the DC resistance in the direction of thickness of the photoconductive elements 7 decreases by the photoconductive effect. As a result, a photoelectric current I_D flows across the electrodes 8′ and 8″ through the photoconductive element layers 7 and the resistance layer 6 to cause a voltage drop Vd in the lateral direction of the resistance layer 6 to thereby create a DC bias voltage (that is, biasing electric field) Vd in the lateral direction of the non-linear ferroeleqtric element layer 5, which bias voltage increases with the increase in the light input L_1. Consequently, the relative dielectric constant in the lateral direction of the non-linear capacitance element layer 5 decreases by the illumination by the input optical image L_1, and resultant reduction in the lateral dielectric amplification leads to decrease of the laterally bypassing alternating current I_A. Thus the luminous output makes an abrupt decrease with the increase in the image input L_1, and a bright, inverted, negative output image L_2 can be obtained when the input image L_1 is applied in the form of extremely dark light rays.

For the highly sensitive operation of the device which is so arranged that the luminescence of the electroluminescent element is controlled by the lateral dielectric amplification action in the manner as described above, it is necessary to select in such a way, for example, that the geometrical mean of the maximum capacitance and the minimum capacitance of the non-linear ferroelectric element layer 5 variable depending on the DC bias voltage is substantially equal to the capacitance of the luminous portion of the electroluminescent element layer 4.

With the prior system, the thickness of the non-linear ferroelectric layer must be made more than 100 times the thickness of the electroluminescent layer in order to have substantially equal capacitances for both the layers. In contrast thereto, it is utterly unnecessary in the electroluminescence device of the invention to have such a thick layer of non-linear ferroelectric element because the dielectric amplification action in the lateral direction thereof, that is, in the direction parallel to the face thereof is utilized as illustrated.

FIG. 4 is an electrical equivalent circuit diagram of the device of FIG. 2. In FIG. 4, symbols R_{PC}, R_R, C_{EL} and C_D denote the resitance of the photoconductive element 7, the resistance of the resistance layer 6, the capacitance of the electroluminescent layer 4 in the direction of thickness thereof, and the capacitance of the nonlinear capacitance element 5 in the lateral direction thereof, respectively. It will be seen from FIG. 4 that an effective AC circuit related with the DC voltage V_D is provided by a series circuit of the capacitances C_{EL} in the direction of thickness of those portions which contribute to the luminescence of the electroluminescent element layer 4 between the electrodes 2′, 2″ and the nonlinear ferroelectric element layer 5 and the capacitance C_D of the non-linear ferroelectric element layer 5 in the lateral direction thereof.

The capacitance of the non-linear ferroelectric element layer 5 in the lateral direction thereof can be made smaller by reducing the thickness of the layer to an extent that it is substantially equal to the above capacitance of the electroluminescent element layer 4. For example, in the present embodiment, the thickness of the element layer 5 can be made extremely thin or in the order of several tens to 100 microns by employing the aforementioned material. Of course, the spacing between the adjacent electrodes 2′ and 2″ may be varied to suitably adjust the capacitance in the lateral direction of the element layer 5.

Furthermore, as apparent from FIG. 2, the photoconductive layer 7 is isolated from the AC circuit and is arranged to make a DC operation so as to utilize a great variation in its DC resistance. By virtue of the above arrangement, this layer can operate at a very high sensitivity. Still further, by selecting the AC voltage V_A at a high frequency for thereby obtaining a lateral AC amplification as high as 1000 times the common value, the electroluminescence device can now be used as a high-amplification image device and the like.

A further embodiment of the invention shown in FIG 3 is substantially similar to the embodiment shown in FIG. 2 except that a non-linear resistance element layer 10 in the form of a semiconductor thin film such as a SiC varistor or CdS film is provided in lieu of the non-linear capacitance element layer 5 in FIG. 2. An equivalent circuit of the device of FIG. 3 is shown in FIG. 5 wherein symbols R_B and R_{PC} denote the lateral resistance of the non-linear resistance element layer 10 and the resistance of a photoconductive layer 7 in the direction of its thickness, respectively.

In this embodiment, decrease of the resistance R_{PC} of the photoconductive layer 7 due to appearance of an optical input L_1 results in an increase of voltage shared by the non-linear resistance element layer **10** and a corresponding decrease of the resistance R_B of the non-linear resistance element layer **10**. Accordingly, with an increase in the optical input L_1, an increased amount of alternating current I_A flows in the direction of thickness of the electroluminescent element layer **4**, and an optical output L_2 is derived therefrom as a positive image.

It will be appreciated from the foregoing description that the invention provides an electroluminescence device of the structure in which the luminescence of its electroluminescent element can be controlled at a high sensitivity by the amplification action of a non-linear impedance element and in which its electroluminescent element need not be resistive because a unidirectional field is applied in the lateral direction of the non-linear impedance layer for the impedance control thereof.

The invention based on such unique principle can visualize various electroluminescence devices which find many useful applications in a variety of industrial fields.

What is claimed is:

1. An electroluminescent device for converting a dark input image into a bright output image, which device comprises an electroluminescent layer, a plurality of pairs of electrodes mounted on one face of said electroluminescent layer, a non-linear impedance layer superposed on the other face of said electroluminescent layer, means for applying a DC bias voltage to said non-linear impedance layer and an AC power source connected alternately with said pairs of electrodes for supplying thereto an AC voltage to energize said electroluminescent layer, wherein the electric current flowing through said electroluminescent layer is caused to flow lengthwise in said non-linear impedance layer.

2. The device as set forth in claim **1**, further comprising an input energy sensitive element through which said DC bias voltage is applied to said non-linear impedance layer, the impedance of said input energy sensitive element being variable with the energy of said input image, wherein said current flowing through said electroluminescent layer is controlled in dependence upon the variation in said impedance.

3. The device as set forth in claim **1**, wherein said impedance layer is a non-linear ferroelectric capacitance element.

4. The device as set forth in claim **1**, wherein said impedance layer is a non-linear semiconductor.

5. An electroluminescent device for deriving a bright negative output image from a dark input image through dielectric amplification of the latter, which device comprises a transparent support base, an electroluminescent layer superposed on said support base, a plurality of pairs of electrically insulated light-transmissive AC electrodes which are interdigitally mounted on one face of said electroluminescent layer at a predetermined spacing from each other layer, a non-linear ferroelectric capacitance element superposed on the other face of said electroluminescent layer, a photoconductive element having a relatively high dark resistance and superposed on said ferroelectric capacitance layer, a DC electrode made of a light-transmissive material and superposed on said photoconductive element, an AC power source connected between said pairs of AC electrodes for supplying an AC voltage thereto, and a DC power source connected with said DC electrode for supplying a DC voltage thereto, wherein the AC voltage applied to said pairs of AC electrodes causes an alternating current to flow across each pair of adjacent AC electrodes by way of said ferroelectric capacitance layer in the lengthwise direction thereof for establishing a strong electric field in said electroluminescent layer in the direction of thickness thereof to cause a luminescence to develop in said electroluminescent layer, whilst as the DC voltage is supplied from said DC power source to said DC electrode and an input optical image is projected onto said DC electrode, the DC resistance in said photoconductive element in the direction of thickness thereof decreases and consequently a photoelectric current flows across said DC and AC electrodes to increase the DC bias voltage across said ferroelectric capacitance element in the direction of thickness thereof with the resultant reduction in the specific dielectric constant of said ferroelectric capacitance layer, which reduction causes said alternating current to decrease for causing the luminous output of the input image to be abruptly decreased with the increase in the input image, whereby a bright output image is derived from said dark input image.

6. The device as set forth in claim **5**, wherein said non-linear ferroelectric capacitance layer is formed of a layer of ferroelectric ceramics.

7. The device as set forth in claim **5**, wherein the spacing between the adjacent AC electrodes is more than twice the thickness of said electroluminescent layer.

8. The device as set forth in claim **5**, wherein the DC resistance of said capacitance layer is smaller than the dark resistance of said photoconductive element.

9. The device as set forth in claim **5**, wherein the DC resistance of the electroluminescent layer is smaller than the DC resistance of said capacitance layer.

10. The device as set forth in claim **5**, wherein the geometrical mean of the maximum and the minimum capacitances of the capacitance layer is substantially equal to the capacitance of the luminous portion of the electroluminescent layer.

11. An electroluminescent device for deriving a bright output image from a dark input image through dielectric amplification of the latter, which device comprises a transparent support base, an electroluminescent layer superposed on said support base, a plurality of pairs of electrically insulated light-transmissive AC electrodes which are interdigitally mounted on one face of said electroluminescent layer at a predetermined spacing from each other, a non-linear ferroelectric capacitance layer superposed on the other face of said electroluminescent layer, an opaque resistance layer mounted on said non-linear ferroelectric capacitance layer, a plurality of pairs of photoconductive elements having a high dark resistance and mounted on said opaque resistance layer at positions opposite to said AC electrodes, a plurality of electrically insulated DC electrodes mounted respectively on said photoconductive elements, an AC power source connected between said pairs of AC electrodes for supplying an AC voltage thereto, and a DC power source connected between said pairs of DC electrodes for supplying a DC voltage thereto, wherein the AC voltage applied to said pairs of AC electrodes causes an alternating current to flow across each pair of adjacent AC electrodes by way of said ferroelectric capacitance layer in the lengthwise direction thereof for establishing a strong electric field in said electroluminescent layer in the direction of thickness thereof to cause a luminescence to develop in said electroluminescent layer, whilst as the DC voltage is supplied from said DC power source to said DC electrode and an input optical image is projected onto the DC electrode, the DC resistance in said photoconductive element in the direction of thickness thereof decreases and consequently a photoelectric current flows across said pair of DC electrodes through said photoconductive elements and said resistance layer to cause a voltage drop across said resistance layer in the lengthwise direction thereof thereby to establish a DC bias voltage in said capacitance layer in the lengthwise direction thereof, which bias voltage increases with the increase in the input optical image with the resultant reduction in the relative dielectric constant of said capacitance layer thereby to cause said alternating current to decrease for causing the luminous output of the input image to be abruptly decreased with the increase in the input image, whereby a bright output image is derived from said dark input image.

12. The device as set forth in claim **11**, wherein said non-linear ferroelectric capacitance layer is formed of a layer of ferroelectric ceramics.

13. The device as set forth in claim **11**, wherein the spacing between the adjacent AC electrodes is more than twice the thickness of said electroluminescent layer.

14. The device as set forth in claim **11**, wherein the DC resistance of said opaque resistance layer is smaller than the dark resistance of said photoconductive element.

15. The device as set forth in claim **11**, wherein the geometrical mean of the maximum and the minimum capacitances of said capacitance layer is substantially equal to the capacitance of the luminous portion of the electroluminescent layer.

16. An electroluminescent device for deriving a bright output image from a dark input image, which device comprises a transparent support base, an electroluminescent layer superposed on said support base, a plurality of pairs of electrically insulated light-transmissive AC electrodes which are interdigitally on one face of said electroluminescent layer at a predetermined spacing from each other, a non-linear resistance layer formed of a thin semiconductor film and superposed on said electroluminescent layer, a plurality of pairs of photoconductive elements having a high dark resistance and mounted on said resistance layer at positions opposite to said AC electrodes, a plurality of electrically insulated DC electrodes mounted on said photoconductive elements, an AC power source connected between said pairs of AC electrodes for supplying an AC voltage thereto, and a DC power source connected with said DC electrodes for supplying a DC voltage thereto, wherein projection of an input image onto said DC electrodes invites a decrease in the resistance of said photoconductive elements, which decrease causes an increase in the voltage across said resistance layer and decrease in the resistance of the same to permit an increased amount of alternating current to flow through said electroluminescent layer in the direction of thickness thereof with the increase in the input image, whereby a bright output image is derived from the dark input image.

17. The device as set forth in claim **16**, wherein said non-linear resistance layer is made of SiC.

18. The device as set forth in claim **16**, wherein the spacing between the adjacent AC electrodes is more than twice the thickness of said electroluminescent layer.

19. The device as set forth in claim **16**, wherein the DC resistance of said resistance element is smaller than the dark resistance of said photoconductive element.

References Cited

UNITED STATES PATENTS

2,969,481	1/1961	Sack	315—169
3,086,143	4/1963	Wolfe	315—169
3,154,720	10/1964	Cooperman	315—169
3,243,508	3/1966	Sclar	315—169 X
3,350,506	10/1967	Chernon	315—169 X
3,387,271	6/1968	Chernon	315—169 X

JOHN W. HUCKERT, Primary Examiner

ANDREW J. JAMES, Assistant Examiner

U.S. Cl. X.R.

340—166; 178—7.3