July 10, 1962 B. KAZAN 3,043,961

ELECTROLUMINESCENT DEVICE AND CIRCUITS THEREFOR

Filed Aug. 26, 1955 2 Sheets-Sheet 1

Fig. 1.

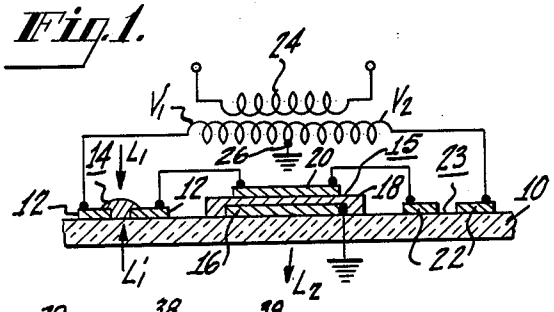
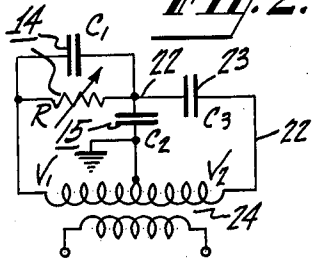


Fig. 2.



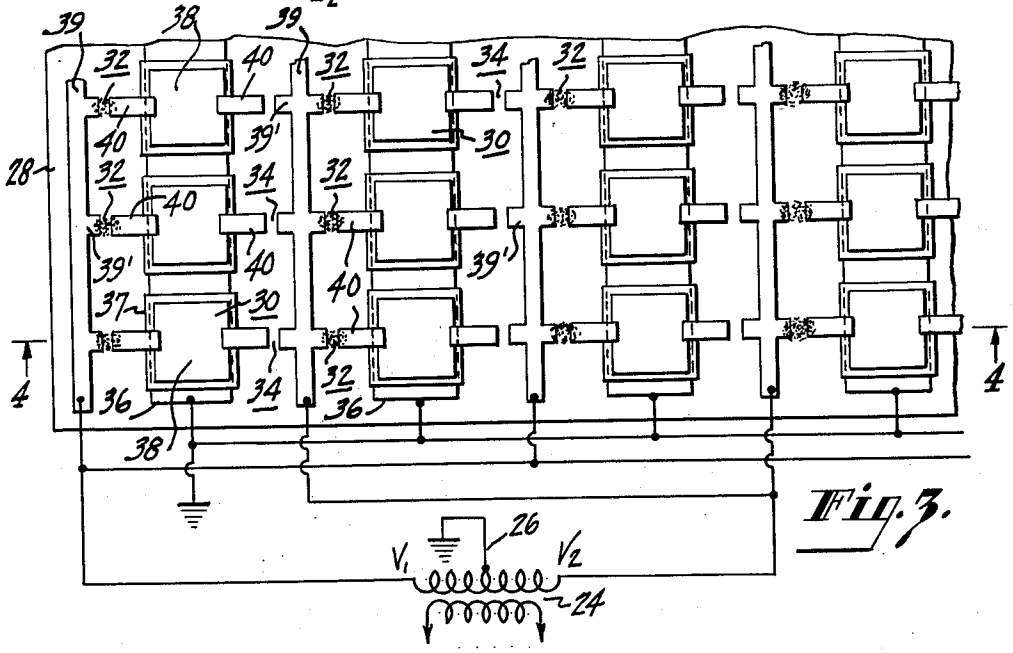


Fig. 3.

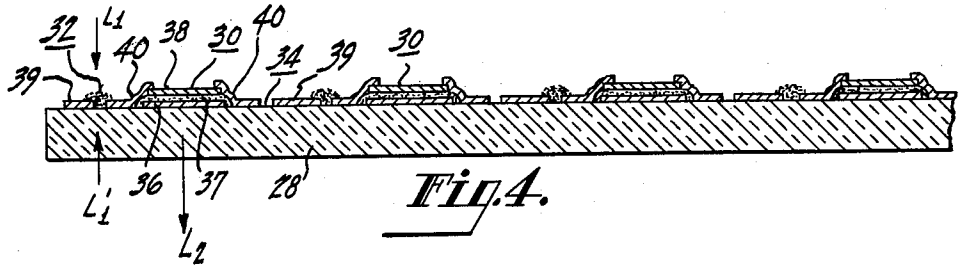


Fig. 4.

INVENTOR.
BENJAMIN KAZAN
BY
William A. Galesak
ATTORNEY

July 10, 1962 B. KAZAN 3,043,961

ELECTROLUMINESCENT DEVICE AND CIRCUITS THEREFOR

Filed Aug. 26, 1955 2 Sheets-Sheet 2

Fig. 5.

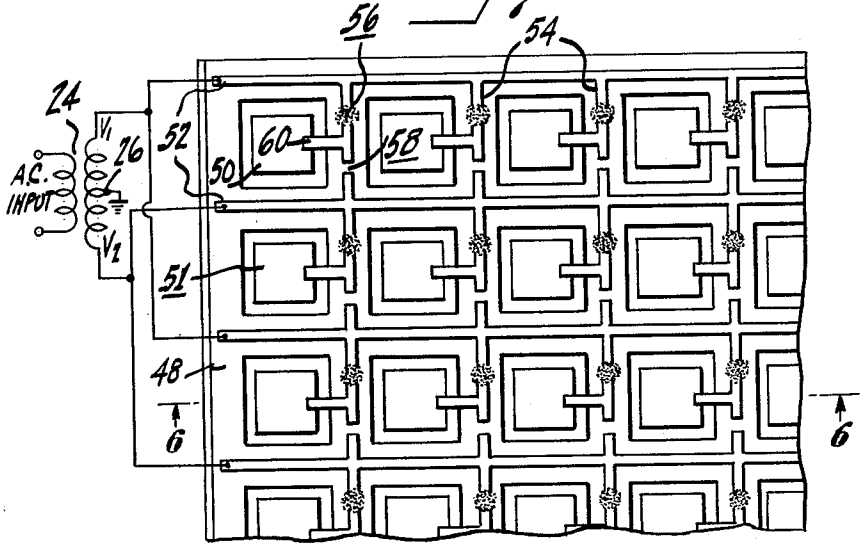


Fig. 6.

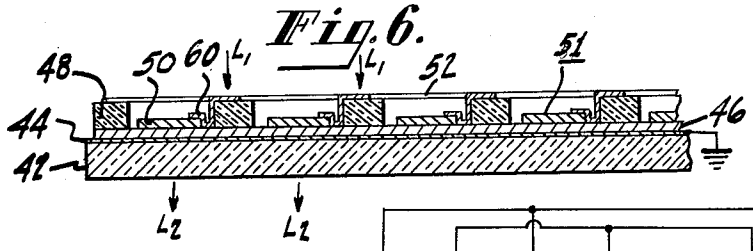
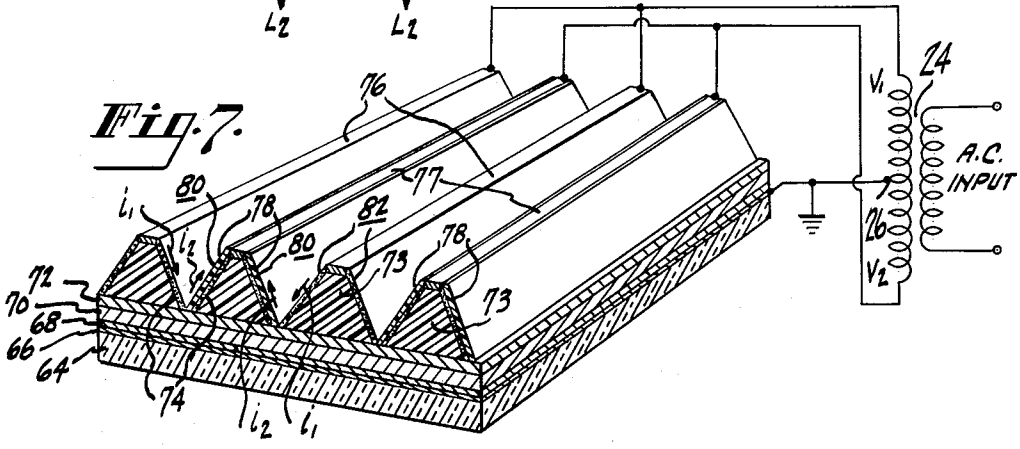


Fig. 7.



INVENTOR.
BENJAMIN KAZAN
BY
William A. Galeski
ATTORNEY

United States Patent Office 3,043,961 Patented July 10, 1962

3,043,961

ELECTROLUMINESCENT DEVICE AND CIRCUITS THEREFOR

Benjamin Kazan, Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Filed Aug. 26, 1955, Ser. No. 530,875
20 Claims. (Cl. 250—213)

This invention relates to electroluminescent devices and circuits therefor designed to serve as radiant energy transducers, such as light amplifiers and radiant energy converters.

It is known that luminescence can be produced in some phosphor materials by subjecting them to a varying electric field or current. The intensity of the luminescence increases with increasing electric field strength. These phosphor materials are known as electroluminescent materials or electroluminescent phosphors, and the property which they exhibit is known as electroluminescence. The combination of a body of electroluminescent material with conductive electrodes on opposite sides thereof is known as an electroluminescent cell. Some examples of electroluminescent materials are zinc sulfide and zinc selenide, activated by copper or manganese, for example.

It is also known that certain materials possess the property of being able to vary their electrical impedance in response to incident radiant energy, the conductivity increasing with increasing radiation. The radiation employed may be visible light, infra-red radiation, ultraviolet radiation, gamma rays, or X-rays, for example. When the materials are responsive to light, they are known as photoconductive materials and the property they exhibit is known as photoconductivity. Some examples of very sensitive photoconductive materials are cadmium sulfide and cadmium selenide in crystalline form.

It has been proposed to intensify light images by means of a projection screen formed of a layer of photoconductive material and a contiguous layer of electroluminescent material sandwiched between two transparent sheet electrodes to which an alternating current voltage is applied. The respective thicknesses of the two layers are chosen for the materials used so that in the dark the impedance of the photoconductive layer is substantially higher than that of the electroluminescent layer. Under these conditions, a greater fraction of the supply voltage will be impressed across the photoconductive layer in the dark than across the electroluminescent layer. The supply voltage is adjusted so that in the dark the voltage appearing across the electroluminescent layer is just below the "threshold" voltage, that is, just below the voltage required to cause visible luminescence.

When a light image is projected onto the surface of the photoconductive layer, the conductivity of the layer is increased in elemental areas in amounts corresponding to the intensity of the light which strikes the photoconductive layer. The impedance of the photoconductive layer in the excited areas drops accordingly, resulting in a decrease in the amount of voltage appearing across the photoconductive layer. A corresponding increase in the electric field impressed across the elemental areas of the electroluminescent layer is produced. Light is thus emitted from elemental areas of the electroluminescent layer which varies in intensity with the strength of the electric field thereacross, so as to produce an amplified light image corresponding to the incoming image.

In such a device, the alternating current source provides the added energy required to achieve amplification of light. Hence, the greater the available voltage, the greater will be the amplification. However, one of the limitations on the amount of voltage which can be impressed on a given device is the current flowing through the electroluminescent layer in the dark. If the current

supplied to the electroluminescent layer in the dark or unilluminated condition is too high, the electroluminescent layer will undesirably emit light. The current in the dark need only be of sufficient magnitude to develop a threshold bias or voltage across the electroluminescent layer.

One of the factors affecting the amount of current flowing through the electroluminescent layer in the dark is the dark resistivity of the photoconductor. Ideally, a photoconductor should have infinite dark resistivity, but in practice the upper limit of dark resistivity of known photoconductive materials is about 10^{13} ohm-cm., hence, the materials are found to produce some measurable dark current. Some of the more sensitive materials such as cadmium sulfide and cadmium selenide have a relatively low dark resistivity. Another factor affecting the amount of current flowing through the electroluminescent layer in the dark is the capacitance of the photoconductive layer. The dark resistance of the photoconductive layer is shunted by the capacitance of the layer, and both make up the impedance of the layer which controls the current passing through the electroluminescent layer in the dark. Both these factors therefore contribute to the current, and the higher the supply voltage the higher will be the current.

In such a device, unless steps are taken to prevent it, light emitted by the electroluminescent layer will feed back to the photoconductive layer and contribute to the photoconductive excitation, causing regeneration, which sometimes is objectionable. Light feedback can be prevented by interposing an opaque layer between the photoconductive layer and the electroluminescent layer. However, a disadvantage of the use of the opaque layer is that it is not possible to project an image and view the output image from the same side with such an arrangement.

An object of this invention is to provide an improved electroluminescent device.

A further object of this invention is to provide means in radiant energy transducer permitting the application of higher operating voltage without producing electroluminescence in the unexcited condition.

Another object of this invention is to provide an electroluminescent image device in which light feedback is prevented without necessitating the use of an opaque layer.

Yet another object of this invention is to provide an electroluminescent image device in the form of a projection screen wherein the output image can be viewed from the same side on which the input image is projected.

In accordance with one feature of this invention, a neutralizing circuit is provided in a light amplifier for applying a current through the electroluminescent element of phase opposite to the current flowing therethrough due to the usual voltage source and the photoconductive element, whereby the net current through the electroluminescent element is reduced. In accordance with one embodiment, a light amplifying screen is provided which is made up of a mosaic of elemental areas, each area including a photoconductive element and an electroluminescent element in series with a first alternating voltage source of given phase. The screen also includes a plurality of constant impedance elements, one in series with each electroluminescent element and in series with a second alternating voltage source 180° out of phase with the first voltage source. Since the two voltages are of opposite phase, the net voltage applied in the dark to the electroluminescent element, and hence, the current through the electroluminescent element itself, is less than it would be in the absence of the neutralizing circuit.

According to another feature of the invention the electroluminescent elements are displaced laterally from the photoconductive elements to prevent light feedback. This

also permits viewing of the output image from the same side on which the incoming image is projected.

Although the invention will be described in connection with the amplification of light images, it will be understood that the invention is also applicable to other radiant energy transducers, such as, for example, devices for converting X-rays, gamma rays, ultra-violet or infra-red images to visible light images.

In the drawings:

FIG. 1 is a sectional view of an elemental device having single elements connected in a circuit and embodying the invention in a simple form;

FIG. 2 is a schematic representation of the elements shown in FIG. 1;

FIG. 3 is an enlarged fragmentary plan view of one form of light amplifying screen embodying the invention;

FIG. 4 is a sectional view taken along lines 4—4 of FIG. 3;

FIG. 5 is an enlarged fragmentary plan view of another form of light amplifying screen embodying the invention;

FIG. 6 is a sectional view taken along lines 6—6 of FIG. 5; and

FIG. 7 is an enlarged fragmentary perspective view partly in section of still another form of light amplifying screen embodying the invention.

Referring to FIG. 1, there is shown a transparent insulating member or glass plate **10** supporting on a surface thereof a pair of laterally spaced conductors **12** forming a gap therebetween. This gap is covered or filled with photoconductive material to form a photoconductive element **14**. Adjacent to the conductors **12** is an electroluminescent cell **15** comprising a small element or square of thin transparent conductive material **16** on the plate **10**, an element or layer of electroluminescent phosphor material **18** on the transparent conductive element **16**, and a conductive element or layer **20** on the electroluminescent element **18** in registry with the transparent conductive element **16**. Supported on the plate **10** adjacent to the electroluminescent cell **15** is a second pair of laterally spaced conductors **22** forming therebetween an open gap constituting a constant impedance element **23**.

The conductive element **20** is electrically connected to one of the conductors **12** and to one of the conductors **22**. The other conductors **12** and **22** are connected respectively, one to each side of the secondary winding of a power transformer **24**. The secondary winding has a tap connection **26**, which is grounded. The transparent conductive element **16** is also grounded.

The material of the photoconductive element **14** may comprise any known photoconductive material sensitive to the type of radiation employed. Preferred materials having high photoconductive sensitivity are cadmium sulfide and cadmium selenide powders, such as those disclosed in a copending application of Charles J. Busanovich and Soren M. Thomsen, Serial No. 472,354, filed December 1, 1954, now U.S. Patent Number 2,876,202. The powders may be mixed with a suitable dielectric binder, such as ethyl cellulose, polystyrene, or Araldite (an epoxy resin) for example, or they may be applied without a binder.

The electroluminescent element **18** may be a layer of any known electroluminescent phosphor material, preferably mixed with a dielectric material, such as ethyl cellulose or polystyrene, for example. Suitable phosphor materials are zinc sulfide activated with copper, and zinc selenide activated with manganese.

The transparent conductive element **16** may be a thin film of tin chloride or tin oxide, for example. The conductors **12** and **22** and the conductive element **20** may be strips, lines, or squares of conductive material, such as aluminum, silver, gold, tin chloride, or tin oxide, for example.

The voltage source **24** is preferably alternating current of several hundred cycles frequency and may have a total secondary voltage of about 1000–2000 volts, depending upon the size of the photoconductive and electroluminescent elements **14** and **18** respectively. For example, the photoconductive element **14** may have a gap width of .020 inch, corresponding to the spacing between the conductors **12**, and a gap length of .040 inch. The electroluminescent element **18** may be square, .040 inch on a side, and may have a thickness of about .001 to .003 inch. The capacity of the open gap formed by the conductors **22** should be approximately equal to the capacity of the gap formed by the conductors **12** without the photoconductive material.

The operation of the device of FIG. 1 will now be described with the aid of FIG. 2 which is a schematic representation thereof. In FIG. 2, the photoconductive element **14** is represented as a variable resistance R, whose resistance decreases when light is incident thereon, in shunt with a capacitance C_1. The electroluminescent cell **15** is represented by a capacitance C_2 in series with the photoconductive element **14** (R and C in parallel) and with a voltage V_1 between the center tap and one output lead of the secondary of source **24**. The above circuit constitutes the light amplifying circuit. The electroluminescent cell **15** or capacitance C_2 is also common to an auxiliary or current neutralizing circuit which includes the constant impedance element **23** or capacitance C_3, representing the open capacitive gap formed by the spaced conductors **22**, in series with the voltage V_2 between the center tap and the other output lead of the secondary of source **24**. It will be appreciated that the voltages V_1 and V_2 are 180° out of phase with each other.

In the absence of the auxiliary or current neutralizing circuit, some amount of current will flow through the electroluminescent cell **15** or capacitance C_2 with no light incident on the photoconductive element **14**. This current flow through C_2 in the dark is due partly to the dark resistance of R and partly to the shunting effect of the capacitance C_1. This current is a limiting factor on the amount of supply voltage V_1, for example, which can be used to operate the device. With increased voltage V_1, a point will be reached where any further increase in voltage will produce sufficient current through C_2 in the dark to cause electroluminescence thereof. This is an undesired condition because the light amplifier should not emit light in the absence of exciting light and should produce output light only when input light is applied to the photoconductive element.

In order to counteract or neutralize the tendency of high current flow through the electroluminescent cell **15** in the dark, the auxiliary circuit of V_2 in series with C_3 is used to apply a voltage across C_2 which is out of phase with the voltage which would be present in the absence of the auxiliary circuit. The net voltage across the electroluminescent cell is therefore much reduced and the resultant current is much lower.

Experimentally, the current through an electroluminescent cell in the dark was reduced, in accordance with the invention, to about 20 percent with an open capacitive gap represented by C_3 and with the voltage V_2 of the auxiliary circuit equal to but opposite in phase from the voltage V_1 of the light amplifying circuit. More complete neutralization may be achieved by filling the open, or neutralizing gap with non-photoconductive material having the same resistivity as the dark resistivity of the photoconductive element **14**. Alternatively, the neutralizing gap may be filled with photoconductive material of the same kind as in the photoconductive element **14** with the gap shielded from incident light, as by an opaque insulating coating over the photoconductive material.

It is sometimes preferable to neutralize just sufficiently to develop a threshold voltage across the electroluminescent cell **15**. That is, it may be desirable to operate the device so that in the dark the voltage appearing across the electroluminescent cell is just below the value of voltage required to cause visible light emission therefrom. Under such conditions, any small amount of light incident

on the photoconductive element 14 will produce increased voltage across the electroluminescent cell and resulting light emission. This operating condition may be achieved by using a variable tap 26 on the secondary of the voltage source 24. This tap may then be moved to the proper setting by noting at which point light from the electroluminescent cell is just barely extinguished in the dark.

In the dark condition of the device including the neutralizing circuit there will be a small bias voltage across the electroluminescent cell 15 or capacitance C_2, which wlil be smaller than it would be in the absence of the neutralizing circuit, and a substantially larger voltage across the parallel combination of R and C_1, or the photoconductive element 14. If, then, low level light, such as L_1 (FIG. 1) is caused to impinge on the photoconductive element 14, the resistance R will drop accordingly and a greater fraction of the supply voltage V_1 will be impressed across the electroluminescent cell 15 or capacitance C_2. The electroluminescent cell 15 will therefore emit light L_2 of greater intensity than the incident light L_1.

It will be appreciated that the auxiliary or neutralizing circuit will have little or no effect on the amplifying properties of the device. Since the alternating current impedance in series with the photoconductive element 14 consists essentially of C_2 and C_3 in parallel, C_3 can be neglected, it being many times higher in impedance than C_2. With the use of a current neutralizing circuit connected to the light amplifying circuit in accordance with the invention, the source voltage such as V_1 may be increased to provide greater light amplification without producing electroluminescence in the dark.

According to another feature of the invention, the physical displacement of the electroluminescent cell 15 with respect to the photoconductive element 14 in the plane of the screen makes it possible to project light on the image screen from one side and view the amplified light from the same side. Referring again to FIG. 1, it will be seen that light L_1', when projected on the surface of the glass plate 10 opposite the surface containing the photoconductive element 14, will be transmitted through the glass plate 10 and strike the under side of the photoconductive element 14. The light L_1' will cause a drop in the resistance of the photoconductive element 14, in the same manner as did the light L_1, thereby producing amplified light L_2 from the electroluminescent cell 15. The amplified light L_2 is thus visible from the same side of the plate 10 on which the incident light L_1' was projected. Because of the lateral displacement of the elements 14 and 13, the output light will not impinge on the photoconductive element 14, and therefore light feedback is avoided.

It will be appreciated that the amount of resistance change in the photoconductive element 14 is a function of the intensity of the incident light L_1 or L_1'. Also, the intensity of the output light L_2 is a function of the voltage applied across the electroluminescent cell 15. Thus, the greater the incident light L_1 or L_1', the greater will be the drop in resistance of the photoconductive element 14 and the greater will be the voltage produced across the electroluminescent cell 15, with the result that the greater will be the output light emission L_2. Consequently, a mosaic of elements such as those shown in FIG. 1 can be used to amplify radiant energy images.

Having thus described the invention in connection with an elemental device incorporating single elements, the invention will now be described in connection with a light amplifying screen incorporating a multiplicity of elements similar to those of FIG. 1 and designed to reproduce amplified images.

Referring to FIGS. 3 and 4, there is shown a screen comprising a transparent insulating support 28, such as glass, having on one surface thereof a mosaic made up of a plurality of elemental areas, each area including an electroluminescent cell 30, a photoconductive element 32, and a constant impedance element 34. In more detail, the support or glass plate 28 bears a plurality of spaced apart, parallel, transparent conductive strips 36. Electroluminescent elements 37, which may be squares of electroluminescent phosphor, are laid down in parallel rows on the conductive strips 36, covering the edges thereof. A plurality of parallel rows of spaced apart conductive elements 38, shown as squares for example, are laid over the electroluminescent squares 37 each in registry with a respective electroluminescent square. Each conductive element 38 and electroluminescent element 37 cooperates with a registering portion of one of the conductive strips 36 to form an electroluminescent cell 30. A network of vertical and horizontal conductors 39 and 40 is laid over the structure thus formed. The vertical conductors 39 are continuous and unbroken, with one conductor 39 disposed in each of the spaces between adjacent rows of electroluminescent cells 30 and in contact with the glass plate 28. Each of the horizontal conductors 40 is connected at one end to a conductive element 38 of an electroluminescent cell 30 and is spaced at its other end from the adjacent vertical conductor 39 to form a gap. As shown, the vertical conductors 39 are provided with lateral extensions 39' each of which forms a part of each gap. The gaps located in alternate spaces between the vertical conductors 39 and the vertical rows of electroluminescent cells 30 are filled with photoconductive material to form the photoconductive elements 32 corresponding to R and C_1 of FIGS. 1 and 2. The unfilled or open gaps constitute capacitive gaps or constant impedance elements 34 corresponding to C_3 of FIGS. 1 and 2. There is thus provided one constant impedance element 34 and one photoconductive element 32 for each electroluminescent cell 30 and electrically connected thereto.

In operation, alternate ones of the elongated vertical conductors 39 are connected together and to one side of secondary of the voltage source 24. The remaining vertical conductors 39 are connected to the other side of the secondary, and the conductive strips 36 are all connected through ground to the tap 26 as shown. Input light L_1 or L_1' representative of an image projected on the screen from either side will produce an amplified image represented by the output light rays L_2, in the manner similar to that hereinbefore described in connection with FIGS. 1 and 2.

In another embodiment, shown in FIGS. 5 and 6, the light amplifying screen comprises a glass plate 42, a transparent conductive coating 44, such as a film of tin chloride thereover, and a layer of electroluminescent phosphor 46 over the transparent coating 44. A multi-apertured insulating spacer or grid 48 is supported on the phosphor layer 46. A multiplicity of conductive elements 50, such as squares of aluminum or silver, are supported on the phosphor layer 46, each of the elements 50 being in registry with a corresponding one of the apertures of the mesh 48. Each conductive element 50 and registering portions of the electroluminescent layer 46 and conductive coating 44 constitutes an elemental electroluminescent cell 51. A network of horizontal and vertical conductors 52 and 54, respectively, is laid down on the other surface of the grid 48. The horizontal conductors 52 are continuous and unbroken. The vertical conductors 54 are broken at regularly recurring points to form a plurality of gaps, alternate ones of which are covered with photoconductive material to form photoconductive elements 56. The uncoated gaps constitute capacitive gaps or constant impedance elements 58. There is one photoconductive element 56 and one constant impedance element 58 adjacent to each conductive element 50 and electrically connected thereto, as by a conductive strip 60. Alternate ones of the horizontal conductors 52 are connected together and to one side of the secondary winding of the voltage source 24, shown with tap 26 grounded. The other horizontal conductors 52 are connected to the opposite side of the secondary winding. The transparent conductive layer 44 is connected to ground. The insulating grid 48 may be of

transparent material such as Lucite if it is desired to project and view the image from the same side.

The operation of the screen shown in FIGS. 5 and 6 is similar to that of FIGS. 3 and 4.

The structure of conductors and gaps on the surface of the grid 48 may be formed by a silk screening process or by evaporating metal through a suitable mask. For example, a network of intersecting lines may be laid down, with gaps provided for the photoconductive and constant impedance elements 56 and 58 respectively. Thereafter, the appropriate gaps would be filled with photoconductive material to produce the photoconductive elements 56, and the remaining gaps would be left open to produce the constant impedance elements 58. In the alternative, all the gaps could be filled with photoconductive material and the appropriate ones covered with opaque insulating material to provide the constant impedance elements 58.

In my copending application filed December 30, 1954, Serial No. 478,707, now U.S. Patent Number 2,949,537, I disclosed the use of a grooved photoconductive surface to permit lateral flow of photocurrents along the sides of the photoconductive surfaces exposed to incident light. The grooves were provided to permit incident light to illuminate a relatively thick photoconductive surface to its full depth. The improvement shown in FIG. 7 consists in shielding portions of the photoconductive surface from incident light to provide constant impedance elements which, when connected in an appropriate neutralizing circuit in accordance with the present invention, will function to reduce the current flowing through the electroluminescent layer in the dark.

Referring to FIG. 7, a panel or screen is provided as a layered structure including a transparent insulating support or glass plate 64, a transparent conductive coating or film 66, a layer of electroluminescent phosphor material 68, a light-opaque insulating layer 70, and a current diffusing resistive layer 72, arranged in that order.

In accordance with the invention, a plurality of close-spaced elements 73 of insulating material in the form of ridges or mound are supported on the current diffusing layer 72. The insulating elements 73 may be made of an epoxy resin such as Araldite, for example. The ridge elements 73 are coated with photoconductive material 74 to form a corrugated photoconductive surface. The crests of the photoconductive surface are provided with elongated conductors 76 and 77, such as lines of silver paint, coextensive with the crests and alternating in sequence. The sides of alternate ones of the coated ridge elements 73 are covered with light opaque insulating material 78. Alternatively, one side only of each coated ridge element 73 may be coated with opaque insulating material. The coating material 78 is shown adjacent to the conductors 77. The conductors 77 are connected together and to one side of the tapped secondary of the voltage source 24. Similarly the conductors 76 are connected together and to the other side of the tapped secondary. The transparent conductive coating 66 is connected to the secondary tap 26 and both are grounded. Each ridge element coated with opaque material 78 constitutes a pair of elongated constant impedance element 80 having substantially the same impedance in the dark as the uncoated ridge elements each of which constitutes a pair of elongated photoconductive or light controlling elements 82. Alternatively, the alternate ridge elements 73 only may be coated with photoconductive material with the other ridge elements 73 coated with a material having the same resistivity as that of the photoconductive material in the dark.

In FIG. 7, if the current-diffusing layer 72 were absent, the photocurrents would flow transversely along the surfaces of those ridge elements 73 which are not covered by opaque material and through a narrow portion of the electroluminescent material 68 lying beneath the lower edge of each side of such ridge elements. However, with the layer 72 the current is diffused or spread to pass through a wider area of the electroluminescent material 68. Each of these wider areas forms part of an elongated electroluminescent cell. In view of the fact that the coating of photoconductive material 74 is rendered conductive only in the areas where light strikes, and retains a high impedance in areas not struck by light, each of the elongated photoconductive elements 82 on the sides of the uncovered ridge elements can be considered as comprising a multiplicity of smaller photoconductive elements. Similarly, each associated elongated portion of the electroluminescent material can be considered as forming parts of a multiplicity of elemental electroluminescent cells.

It will be seen that one portion V_1 of the secondary voltage is applied across that portion of the panel or sandwich between the transparent conductive coating 66 and the conductors 76 associated with the photoconductive elements 82, thus constituting the light amplifying circuit. The auxilary of current neutralizing circuit is constituted by that portion of the sandwich between the transparent conductive coating 66 and the conductors 77 associated with the constant impedance elements 80 and connected across the other portion V_2 of the secondary voltage.

The operation of the device will now be described. Assume the light amplifying screen to be in the dark, and further assume the voltage applied to the light amplifying circuit at a given instant of time to be of such phase as to send current through the photoconductive elements 82 in the direction indicated by the arrows i_1. The voltage applied to the current neutralizing circuit will be opposite in phase to the first mentioned voltage and will therefore send current through the constant impedance elements 80 in a direction indicated by the arrows i_2 which is opposite to the first mentioned current i_1. The opposing currents i_1 and i_2 will converge at the bottom of the ridges and tend to flow through the remaining layers of the screen in opposite directions. The net current through the electroluminescent layer will thus be a reduced current equal to the difference between the two currents i_1 and i_2. By proper adjustment of the relative impedances of the constant impedance elements 80 and the photoconductive elements 82, as by selection of materials and coating thicknesses, and by proper adjustment of the relative phase and magnitude of the voltages applied, the net current flowing through the electroluminescent layer 68 in the dark can be adjusted to produce a current below threshold for electroluminescence. Thereafter, light incident on the photoconductive elements 82 will be reproduced as amplified light from the electroluminescent layer 68.

The photoconductive material 74 may be applied by spraying or settling photoconductive powder over the elongated ridges 73, or if desired, it may be applied by evaporation or sublimation.

Inasmuch as the light which strikes the ridges making up the constant impedances elements 80 would normally be wasted, provision may be made for reflecting such light so that it impinges on the next adjacent photoconductive surface. This may be accomplished by using a material for the opaque insulating coating 78 which provides a good light reflecting surface. A white lacquer is suitable for this purpose. In this way more efficient use can be made of the incident light.

The current diffusing layer 72 may be made of such thickness as to produce a fanning out or spreading of the photocurrents to regions opposite the constant impedance elements. By so spreading the photocurrents, the output light will be emitted from practically the entire electroluminescent surface.

The material for the current diffusing layer may comprise conducting CdS:Cl powder, which may be mixed with an insulating binder such as ethyl cellulose, polystyrene, or Araldite (an epoxy resin) for example. The current diffusing powder may be prepared as follows:

An intimate mixture of 100 grams of cadmium sulfide, 10 grams of cadmium chloride, 1 gram of ammonium

chloride, and 250 milliliters of water is prepared. This mixture may be prepared in a blender such as is used for mixing powders with water. The yellow, viscous liquid is dried at about 150° C. for about 15 hours. The dried cake is then broken up into pea-size lumps and packed into a 12 inch test tube to a depth of about seven inches. The tube is provided with a stopper having an inlet tube therethrough for the purpose of maintaining a substantially stagnant atmosphere in the test tube while maintaining atmospheric pressure through the subsequent firing steps. The test tube filled with the dried mixture is fired at about 700° C. for about 20 minutes and the fired product is then removed from the test tube and allowed to soak in water until it disintegrates. This ordinarily takes about 20 minutes. The product is washed on a fine, sintered, glass filter, dispersing the cake once or twice in water until the washings contain less than 0.01 M cadmium chloride.

What is claimed is:

1. A radiant energy transducer comprising an electroluminescent cell, an element of a material whose impedance is variable with incident radiant energy, a constant impendance element, one side of each of said cell and said elements being electrically connected together, and means connected to the other sides of said elements and said cell for applying a first voltage in series with said cell and said variable impedance element and a second voltage in series with said cell and said constant impedance element.

2. A radiant energy transducer comprising an electroluminescent cell having a predetermined threshold voltage for producing visible light, an element of a material whose impedance is variable with incident radiant energy, a constant impedance element, one side of each of said cell and said elements being electrically connected together, and means connected to the other sides of said elements and said cell for applying a first alternating current voltage in series with said cell and said variable impedance element and a second alternating current voltage in series with said cell and said constant impedance element, the amplitudes and phases of said two voltages and the impedances of said elements and cell being so related that the next voltage applied to said cell in the absence of incident radiant energy on said variable impedance element is below said threshold voltage.

3. A transducer as in claim 2, in which said voltages are substantially equal in amplitude.

4. A transducer as in claim 2, in which the respective impedances of said elements are substantially equal in the absence of incident radiant energy.

5. An electroluminescent device comprising an insulating support having thereon a multiplicity of separate areas of electroluminescent material and of material having a variable impedance characteristic in response to radiant energy, each of said electroluminescent areas being laterally spaced on said support from a corresponding one of said variable impedance areas and responsive to changes in the conductivity of said one variable impedance area due to incident light thereon so as to emit light, said variable impedance areas being positioned out of the direct path of said emitted light.

6. An electroluminescent device comprising a screen made up of an insulating suport having on one side thereof a mosaic of elemental areas, each area including an element of a materail having a variable impedance characteristic in response to radiant energy and an electroluminescent cell connected to and laterally spaced from said element and responsive to changes in the conductivity of said element due to incident light thereon so as to emit light, said variable impedance element being positioned out of the direct path of said emitted light and exposed to incident light on the same side of said device from which said electroluminescent cell emits light.

7. An electroluminescent device comprising an insulating support, a plurality of spaced apart conductive strips on said support, a row of electrically separate conductive elements above each of said strips, electroluminescent material intermediate each strip and its respective row of elements, an elongated conductor positioned between two adjacent rows of conductive elements, means including material having a variable impedance characteristic in response to radiant energy connecting each of said conductive elements to only one adjacent conductor of said conductors, and means providing open gaps between each of said conductive elements and the adjacent one of said conductors not connected thereto.

8. An electroluminescent image device comprising a screen made up of a mosaic of elemental areas; each area including an electroluminescent cell having two terminal means on one side and a third terminal separated from said two terminal means by electroluminescent material, at least one conductor spaced laterally along said screen from each of said cells, and an element of a material whose impedance is variable with incident radiant energy interposed between and connected to said conductor and one of said two terminal means of one of said cells, said conductor being spaced from the other of said two terminal means of an adjacent cell, at least one of said terminals being of a material transparent to incident radiant energy; and means for applying a potential difference between said conductor and said third terminal of each of said cells.

9. An electroluminescent device comprising an insulating support, a mosaic of elemental areas on said support, said mosaic including a plurality of spaced apart elongated conductors and conductive strips in alternate array, electroluminescent phosphor material on said strips and in registry therewith, a row of conductive elements on said phosphor material in registry with each of said strips, material whose impedance is variable with incident radiant energy in alternate ones of the spaces between said conductors and said strips, said variable impedance material in each alternate space being connected on one side to an adjacent one of said conductors and on the other side to adjacent conductive elements, and a row of constant impedance elements in each of the other spaces between said conductors and said strips, said constant impedance elements in each of said spaces being connected on one side to adjacent conductive elements and on the other side to an adjacent one of said conductors.

10. An electroluminescent image device as in claim 9 wherein said variable impedance material constitutes separate photoconductive gaps between said conductors and each of said elements.

11. An electroluminescent image device as in claim 10 wherein the impedances of said photoconductive gaps and said constant impedance elements are substantially equal in the absence of incident radiant energy.

12. An electroluminescent image device comprising a transparent support, a transparent conductive coating on a surface of said support, a layer of electroluminescent phosphor material on said coating, an insulating support member having a surface on said phosphor layer and having a multiplicity of apertures arranged in parallel rows, a plurality of conductive elements on said phosphor, each in registry with one of said apertures of said support member, a plurality of constant impedance elements and elements of a material whose impedance is variable with incident radiant energy on the other surface of said support member, one variable impedance element and one constant impedance element adjacent to each of said conductive elements and connected thereto, and conductive means connecting all of said variable impedance elements for each row together, and conductive means connecting all of said constant impedance elements for each row together.

13. An electroluminescent image device comprising a transparent support, a transparent conductive coating on a surface of said support, a layer of electroluminescent

phosphor material on said coating, an insulating member having a surface on said phosphor layer and having a multiplicity of apertures, a plurality of conductive elements on said phosphor layer one in each of the apertures of said support member, a plurality of constant impedance elements and elements of a material whose impedance is variable with incident radiant energy on the other surface of said support member, one variable impedance element and one constant impedance element adjacent to each of said conductive elements and connected thereto, a plurality of conductors on said other surface of said support member connecting the variable impedance element of one conductive element with the constant impedance element of a conductive element of the next adjacent row.

14. An electroluminescent image device comprising a transparent support member, a transparent conductive coating on said support member, a layer of electroluminescent phosphor material on said coating, and a surface of material whose impedance is variable with incident radiant energy adjacent to said electroluminescent layer, said surface having a plurality of grooves thereacross forming ridges therebetween, one side of each groove being coated with opaque insulating material with the other side exposed to incident light, and conductive material on the crests of said ridges.

15. An electroluminescent image device comprising a transparent support member, a transparent conductive coating on said support member, a layer of electroluminescent phosphor material on said coating, and a surface of material whose impedance is variable with incident radiant energy adjacent to said electroluminescent layer, said surface having a plurality of grooves thereacross forming ridges therebetween, alternate ones only of the ridges formed by said grooves being coated on both sides with opaque insulating material and conductive material on the crests of said ridges.

16. An electroluminescent image device comprising a transparent support member, a transparent conductive coating on said support member, a layer of electroluminescent phosphor material on said coating, a plurality of closely-spaced ridge elements of insulating material adjacent to said electroluminescent layer and forming grooves therebetween said elements having surfaces at an angle to the plane of said support member, one side of each groove being coated with photoconductive material, the other side of each groove being coated with a constant impedance material having a resistivity substantially equal to that of said photoconductive material in the dark, and a conductor on the crest of each of said ridge elements.

17. An electroluminescent image device as in claim 16 wherein said constant impedance coatings have light reflecting surfaces.

18. An electroluminescent image device as in claim 16 wherein a current diffusing layer is interposed between said electroluminescent layer and said ridge elements.

19. An electroluminescent image device as in claim 18 wherein a light opaque insulating layer is interposed between said electroluminescent layer and said current diffusing layer.

20. A radiant energy transducer comprising an electroluminescent cell, an element of a material whose impedance is variable with incident radiant energy, a constant impedance element, one side of each of said cell and said elements being electrically connected together, the other sides of said elements and said cell being mutually insulated to permit application of a first voltage across said other sides of said cell and said variable impedance element and a second voltage across said other sides of said cell and said constant impedance element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,160,383	Kannenberg	May 30, 1939
2,721,808	Roberts et al.	Oct. 25, 1955
2,728,025	Weimer	Dec. 20, 1955
2,728,815	Kalfaian	Dec. 27, 1955
2,743,430	Schultz et al.	Apr. 24, 1956
2,773,992	Ullery	Dec. 11, 1956
2,818,511	Ullery et al.	Dec. 31, 1957
2,837,661	Orthuber et al.	June 3, 1958

OTHER REFERENCES

Mellon Institute of Industrial Research, "Electro-Optical Transducers or Switches," Part 3, Quarterly Report No. 3, Second Series of the Computer Components Fellowship #347 April 1, 1954 to June 30, 1954, pages 1–4.