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S. YANDO

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ELECTROLUMINESCENT DISPLAY DEVICE

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Fig. 1

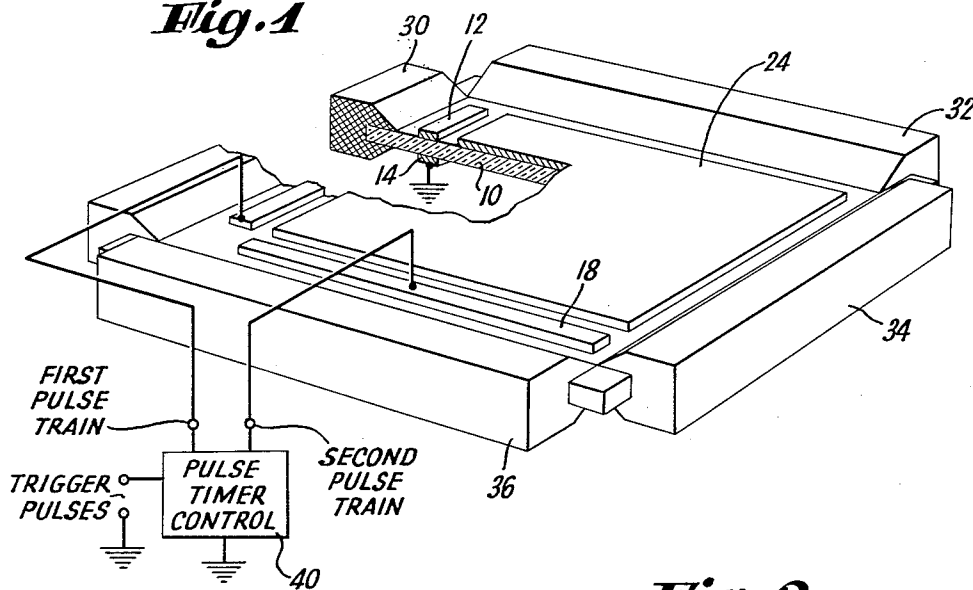


Fig. 2

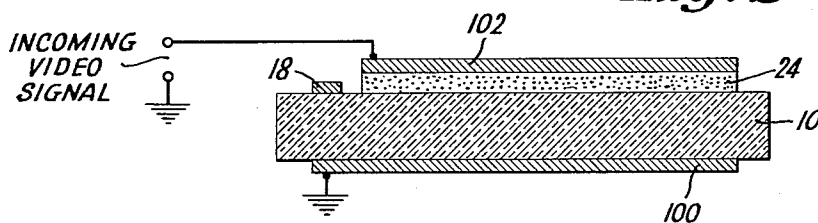
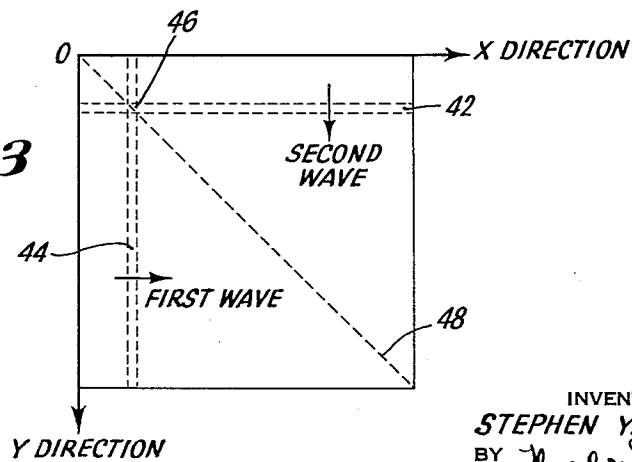


Fig. 3



INVENTOR
STEPHEN YANDO
BY *Theodore Jay H*
ATTORNEY

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ELECTROLUMINESCENT DISPLAY DEVICE

Stephen Yando, Huntington, N.Y., assignor to Sylvania

Electric Products Inc., a corporation of Delaware

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My invention relates to display devices.

Electroluminescent phosphors, when under the influence of an externally applied electric field, will luminesce, the intensity of the emitted light being a function of the strength of this applied field. Consequently, films or layers formed from such phosphors can be used as transducers for transforming electrical energy to light energy.

When a first set of separate horizontal electrodes are secured to one surface of an electroluminescent layer and a second set of separate vertical electrodes are secured to the opposite surface of the electroluminescent layer, a crossed-grid structure is formed wherein a portion of the layer (defined as a cell) is connected between one horizontal conductor and one vertical conductor. When a suitable electric potential difference is applied between any one horizontal-vertical conductor pair, the cell connected between this pair will luminesce.

Further, these applied potentials can be switched or commutated in such manner as to successively energize each cell in turn, thus producing an effect analogous to a scanning action in a cathode ray tube.

I have invented a new type of electroluminescent display device which also produces a "scanning" action and yet which does not utilize either the two sets of horizontal and vertical conductors or the external switching circuitry, as required by the crossed-grid structure.

Accordingly, it is an object of my invention to provide a new type of electroluminescent display device which exhibits a "self-scanning" action.

Another object is to improve electroluminescent display devices by eliminating the necessity of using external switching circuitry.

Still another object is to provide an electroluminescent display device which, under the control of two or three separate signals, can product a television type image display.

These and other objects of my invention will either be explained or will become apparent hereinafter.

In accordance with the principles of my invention, I provide a rectangular sheet of piezoelectric material. This sheet is provided with first, second, third and fourth edges, each of the second and fourth edges extending between the first and third edges. First and second electrodes are respectively secured to opposite surfaces of this sheet adjacent the first edge. Third and fourth electrodes are respectively secured to opposite surfaces of the sheet adjacent the second edge.

An electroluminescent layer is placed in intimate engagement with one surface of the sheet and is separated from the appropriate electrodes.

All four edges of the sheet are terminated in such manner as to absorb, substantially without reflection, any incident elastic wave supplied thereto from the sheet.

A first signal, for example, a first voltage pulse, is applied between the first and second electrodes. This first pulse produces, in the region of the sheet subtended by the first and second electrodes, a mechanical strain proportional to the amplitude of the first pulse. As this strain changes, a disturbance in the form of a first elastic wave accompanied by a first electric field, propagates from the first edge of the sheet towards the third edge where it is absorbed substantially without reflection. The intensity of the first electric field is proportional to the time rate of change of the strain that produced it; stated differently, the intensity of the first field is proportional to the first time derivative of the first pulse.

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Similarly, a second signal, for example a second voltage pulse, is applied between the third and fourth electrodes and produces a second elastic wave, accompanied by a second electric field, which propagates from the second edge of the sheet toward the fourth edge where it is absorbed substantially without reflection. The intensity of the second electric field is proportional to the first time derivative of the second pulse.

Due to the position of the various electrodes, the first and second waves propagate in mutually perpendicular directions. The first and second waves propagate along the sheet, intersect at a small confined region or point, and then continue to propagate, the point of intersection propagating therealong, to generate a line of intersection. The intensities of the first and second electric field are additive at this point of intersection; the resultant total electrical field intensity at this point produces in the electroluminescent layer a spot of light at a position coinciding with this point of intersection. The amount of light emitted by this spot is determined by the total field intensity and increases monotonically therewith. Thus, as the moving point of intersection generates a line of intersection, the moving spot of light generates a line of light.

The first and second edges of the piezoelectric sheet can be regarded as representing the ordinate and abscissa of a rectangular coordinate system having an origin defined by the vertex formed by these edges.

When the first and second pulses arrive at the corresponding electrode pairs in time coincidence, the line of light extends outward from the origin at fixed angles with respect to the ordinate and abscissa. When the relative timing of these pulses is varied so that the second pulse leads the first pulse, the line of light, while maintaining the same fixed angles with respect to the ordinate and abscissa, extends outward from a point on the ordinate displaced from the origin, the ordinate displacement increasing as the time separation of the pulses increases.

Similarly, when the first pulse leads the second pulse, the line of light, while maintaining the same fixed angles, extends outward from a point on the abscissa displaced from the origin, the abscissa displacement increasing as the time separation of the pulses increases.

Thus, by suitably varying the relative timing of the first and second pulses, a plurality of parallel lines of light can be produced in a manner directly analogous to the production of a raster in a cathode ray tube.

These lines of light, however, are unmodulated. In order to modulate these lines of light, I replace the two electrodes on the one surface of the sheet opposite to the surface carrying the electroluminescent layer with a first conductive film covering this one surface. Further, I apply a second conductive film (which is transparent) over the exposed surface of the electroluminescent layer.

When a modulation signal, for example a video signal, is applied between the two films, a third electric field is produced across the entire electroluminescent layer. The intensity of the third field is additive with the summation of the first and second electric fields at any point of intersection of the first and second waves; as a result, the intensity of the light produced at this point varies with the modulation signal. Thus, all of the lines of light can be modulated as desired and a television type image can be displayed.

Illustrative embodiments of my invention will now be described with reference to the accompanying drawings wherein:

FIG. 1 is an isometric view of one embodiment of my invention;

FIG. 2 is a cross-sectional view of another embodiment of my invention; and

FIG. 3 is a plot of elastic wave patterns as established in the devices of FIGS. 1 and 2.

Referring now to FIG. 1, there is shown a thin rectangular sheet 10 of piezoelectric material; in this example, the material is a polarized ceramic strip composed of a sintered lead titanate-lead zirconate mixture. First and second electrodes 12 and 14, which extend across substantially the entire width of the sheet, are secured to opposite surfaces of the sheet adjacent the left edge thereof. Similarly, third and fourth electrodes 18 and 20, which extend across substantially the entire length of the sheet, are secured to opposite surfaces of the sheet adjacent the top edge thereof. An electroluminescent layer 24 is placed in intimate contact with one surface of sheet 10 and spaced apart from the electrodes 12 and 18.

Each edge of the sheet is terminated in such manner as to absorb, substantially without reflection, any incident elastic wave propagating in said sheet. This is accomplished by coating the edges and immediately adjacent portions of strip 10 with a material, such as lead, to provide terminations 30, 32, 34 and 36.

First and second voltage pulses are applied between electrodes 12 and 14 and electrodes 18 and 20, respectively. Each pulse establishes a corresponding electric field within a corresponding portion of the sheet subtended between the corresponding electrodes. The electric field intensity is proportional to the instantaneous value of the appropriate voltage pulse.

Due to the piezoelectric characteristics of strip 10, each electric field produces, in the corresponding section, a mechanical strain proportional to the instantaneous field intensity. Hence, this strain is proportional to the instantaneous value of the corresponding pulse. The strain produces a disturbance which is proportional to the time rate of change of the strain and, consequently, is also proportional to the first time derivative of the corresponding pulse. This disturbance propagates along the sheet in the form of oppositely directed elastic waves.

More particularly, the first pulse produces a first elastic wave which travels from the left edge of sheet 10 toward the right edge. This wave extends across the entire width of sheet 10. (The first pulse also produces an oppositely directed wave which is absorbed almost immediately in termination 30 and has no influence upon the operation of my device.) The second pulse produces a second elastic wave which travels from the upper edge toward the lower edge of the strip. This wave extends across the entire length of sheet 10. (The second pulse also produces an oppositely directed wave which is absorbed in termination 34.)

Each of the first and second waves, due to the piezoelectric effect, is accompanied by an electric field, the intensity of which is proportional to the first time derivative of the appropriate control pulse. The widths of the wave fronts of these waves are substantially identical and can be of the same order as the width of sheet 10 (which can be, for example, 30 mils.). The accompanying electric fields are efficiently coincident in space with the wave fronts. The two propagating waves intersect in a small confined region which can be regarded as a point. (Actually, the region is a square, the length of each side being about 30-40 mils.) The intensities of both electric fields are additive at this point; the resultant field produces in the electroluminescent layer a spot of light at a position corresponding to the point of intersection. The amount of light produced is determined by the summation of the electric field intensities and increases monotonically therewith. As the waves continue to propagate, a line of intersection, and thus a line of light is produced. (Each of the first and second travelling electric fields also tends by itself to produce a moving spot of light in the manner described in more detail in my copending patent application Serial No. 784,212, filed December 31, 1958, now Patent No. 2,917,669. However, these effects can be ignored, the non-linear voltage-brightness characteristic of electro-

luminescent phosphors are such that any background lighting produced by each separate field is insignificant as compared to the light produced at the point of intersection.

As shown in FIG. 3, the top and left edges of sheet 10 can be regarded as representing the abscissa and ordinate of a rectangular coordinate system having an origin defined by the vertex O of these edges.

When the first and second voltage pulses arrive in time synchronism at the corresponding electrode pairs, the line of intersection 48 of the first and second waves (which, as indicated previously, is a line of light) will extend outward from the vertex at fixed angles with respect to the ordinate and abscissa.

Each elastic wave propagates along the sheet with the same velocity V (which is a constant determined by the characteristics of the particular piezoelectric material used). Hence, when the two pulses arrive at the corresponding electrode pairs in time synchronism, the line of light 48 will extend outward from the origin at equal angles of 45° with respect to the ordinate and abscissa; i.e. this line is effectively a diagonal of the square.

When the second pulse leads the first pulse, the line of light will be displaced downward and will extend outward from some point of the ordinate. In particular, when the time of lead is K, then the line will be extremely short and will be positioned at the extreme lower left corner of the sheet. (K is the time required for an elastic wave propagated with the velocity V to travel from one edge of the electroluminescent layer to the opposite edge of the layer.)

Conversely, when the second pulse lags the first pulse, the line of light will be displaced upward and will extend outward from some point on the abscissa. When the time of lag is K, then the line will again be extremely short and will be positioned at the extreme upper right corner of the sheet.

Thus, by smoothly varying the relative timing of the first and second pulses, a raster of lines of light can be produced.

The scanning action can be carried out in the following manner. A pulse time control circuit 40 (FIG. 2) responsive to incoming trigger pulses produces first and second pulse trains. The first pulse train, which contains x separate first control pulses (where x is the number of different lines of light to be produced), is applied between electrodes 12 and 14. The first control pulses are generated at a fixed recurrence frequency; i.e. these first pulses are equidistantly spaced in time. The second pulse train, which contains x separate second control pulses, is applied between contacts 18 and 20. The relative timing of each Nth pulse in the second train (where N is any integer from 1 to x) with respect to the corresponding Nth pulse in the first train must be smoothly varied from $+K$ to $-K$. More particularly, the scanning operation is initiated when the first pulse in the first train lags the first pulse in the second train by K and is completed when the xth pulse in the second train lags the xth pulse in the first train by K. A description of circuit 40 for producing these pulse trains, together with appropriate waveforms, will be found in my copending application Serial No. 784,212 filed December 31, 1958.

It is desired that the electroluminescent layer be excited by sharp spike-like pulses. Due to the differentiating action of the sheet 10, the pulses in both trains should have a sawtooth waveform to provide this type of excitation.

For this type of scanning operation, the recurrence frequency of the first pulse train is preferably not higher than the quantity $\frac{1}{2} K$ where the frequency is expressed in cycles per second and K is expressed in seconds. Should higher frequencies be used, for example, the elastic wave produced by a single pulse applied to one set of electrodes can successively intersect with waves produced by two or more pulses applied to the other set of electrodes.

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Under these conditions, several lines of light can be present substantially simultaneously at different positions on the sheet.

The lines of light thus produced are unmodulated. In order to modulate these lines, the structure of FIG. 1 should be modified as shown in FIG. 2. More particularly, in FIG. 2 the electrodes 14 and 20 are replaced by a single conductive film 100, and another conductive film 102 is applied over the exposed surface of the electroluminescent layer 24.

A video type signal, for example a pulse train of amplitude modulated pulses, is applied between films 100 and 102. As this signal varies, the varying electric field produced in the electroluminescent layer by this signal is added to the summation of the first and second fields produced at any point of wave intersection. Consequently, the light intensities of these points are modulated in accordance with the video signal, and one or all of the lines of light can be modulated as desired.

What is claimed is:

1. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; first and second electrodes secured to opposite surfaces of said sheet adjacent said first edge; third and fourth electrodes secured to said opposite surfaces adjacent said second edge of said sheet; and an electroluminescent layer placed in intimate engagement with one of said surfaces and spaced apart from said first and third electrodes, said electroluminescent layer and said first and third electrodes being coplanar.

2. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; first and second electrodes secured to opposite surfaces of said sheet adjacent said first edge; third and fourth electrodes secured to said opposite surfaces adjacent said second edge of said sheet; an electroluminescent layer placed in intimate engagement with one of said surfaces and spaced apart from said first and third electrodes, said electroluminescent layer and said first and third electrodes being coplanar; and first, second, third and fourth terminations affixed to corresponding edges of said sheet, said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said sheet.

3. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; a conductive film secured to one surface of said sheet; a first electrode applied to the opposite surface of said sheet adjacent said first edge; a second electrode applied to said opposite surface adjacent said second edge; and an electroluminescent layer placed in intimate engagement with said opposite surface and spaced apart from said first and second electrodes, said electroluminescent layer and said first and second electrodes being coplanar.

4. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; a conductive film secured to one surface of said sheet; a first electrode applied to the opposite surface of said sheet adjacent said first edge; a second electrode applied to said opposite surface adjacent said second edge; an electroluminescent layer placed in intimate engagement with said opposite surface and spaced apart from said first and second electrodes, said electroluminescent layer and said first and second electrodes being coplanar; and a second conductive film secured to the exposed surface of said electroluminescent layer, said second film being light transparent.

5. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending

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between said first and third edges; a conductive film secured to one surface of said sheet; a first electrode applied to the opposite surface of said sheet adjacent said first edge; a second electrode applied to said opposite surface adjacent said second edge; an electroluminescent layer placed in intimate engagement with said opposite surface and spaced apart from said first and second electrodes, said electroluminescent layer and said first and second electrodes being coplanar; a second conductive film secured to the exposed surface of said electroluminescent layer, said second film being light transparent; means to apply a first signal between said first electrode and said first film; means to apply a second signal between said second electrode and said first film; and means to apply a third signal between said second and first films.

6. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; first and second electrodes secured to opposite surfaces of said sheet adjacent said first edge; third and fourth electrodes secured to said opposite surfaces adjacent said second edge of said sheet; an electroluminescent layer placed in intimate engagement with one of said surfaces and spaced apart from said first and third electrodes, said electroluminescent layer and said first and third electrodes being coplanar; first, second, third and fourth terminations affixed to corresponding edges of said sheet, said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said sheet; means to apply a first signal between said first and second electrodes; and means to apply a second signal between said third and fourth electrodes.

7. A device as set forth in claim 6 wherein each of said first and second signals is constituted by a corresponding pulse train.

8. An electroluminescent device comprising a four sided sheet of piezoelectric material having first, second, third and fourth edges, said second and fourth edges extending between said first and third edges; a conductive film secured to one surface of said sheet; a first electrode applied to the opposite surface of said sheet adjacent said first edge; a second electrode applied to said opposite surface adjacent said second edge; an electroluminescent layer placed in intimate engagement with said opposite surface and spaced apart from said first and second electrodes, said electroluminescent layer and said first and second electrodes being coplanar; a second conductive film secured to the exposed surface of said electroluminescent layer, said second film being light transparent; means to apply a first pulse train between said first electrode and said first film; means to apply a second pulse train between said second electrode and said first film; and means to apply a video type signal between said second and first films.

9. A device as set forth in claim 8 wherein the pulses in said first and second trains have a sawtooth waveform.

10. An electroluminescent device comprising a rectangular sheet of piezoelectric material; electrode means secured to one surface of said sheet; a first electrode secured to the opposite surface of said sheet adjacent one side thereof; a second electrode secured to said opposite surface adjacent another side thereof, said first and second electrodes extending in substantially orthogonal directions; and an electroluminescent layer secured to said opposite surface and spaced apart from both of said electrodes.

11. A device comprising a rectangular sheet of piezoelectric material; electrode means secured to one surface of said sheet; a first electrode secured to the opposite surface of said sheet adjacent one side thereof; a second electrode secured to said opposite surface adjacent another side thereof, said first and second electrodes extending in substantially orthogonal directions; means to apply a first electrical signal between said first electrode and said electrode means; means to apply a second electrical sig-

nal between said second electrode and said electrode means; and means positioned adjacent said opposite surface and spaced apart from said electrodes, said means being responsive to the electrical fields established within said sheet by said signals.

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