Dec. 15, 1959 S. YANDO 2,917,669

ELECTROLUMINESCENT DEVICE

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Fig. 2

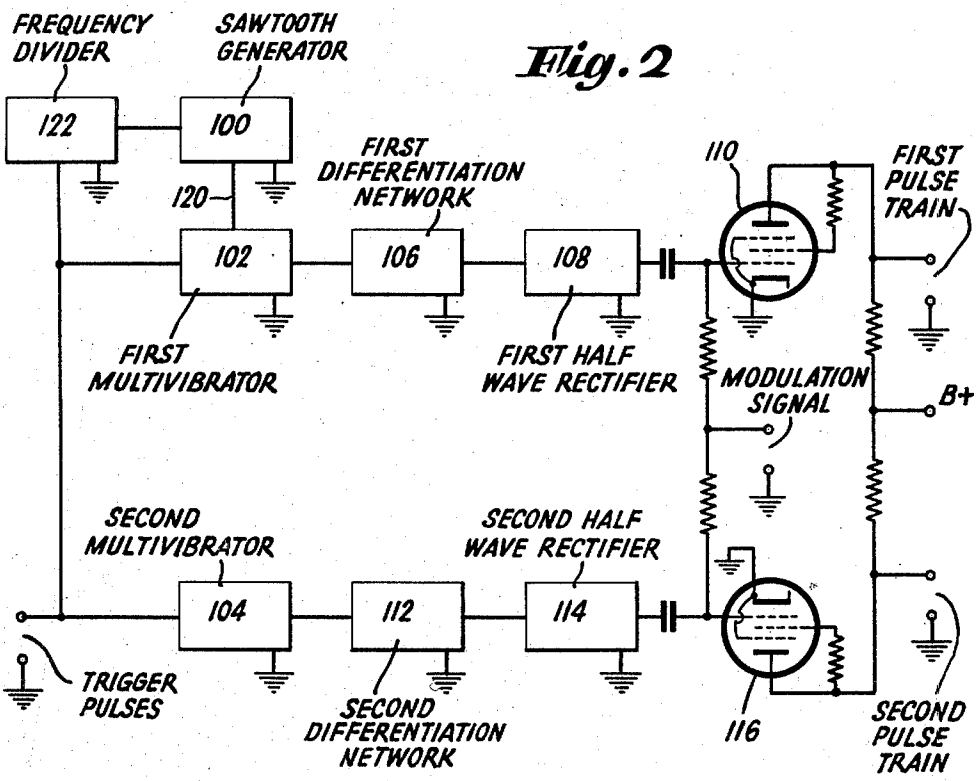
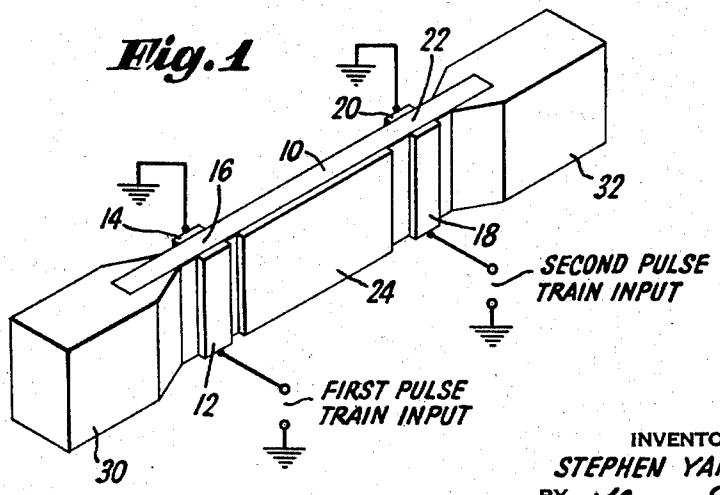


Fig. 1



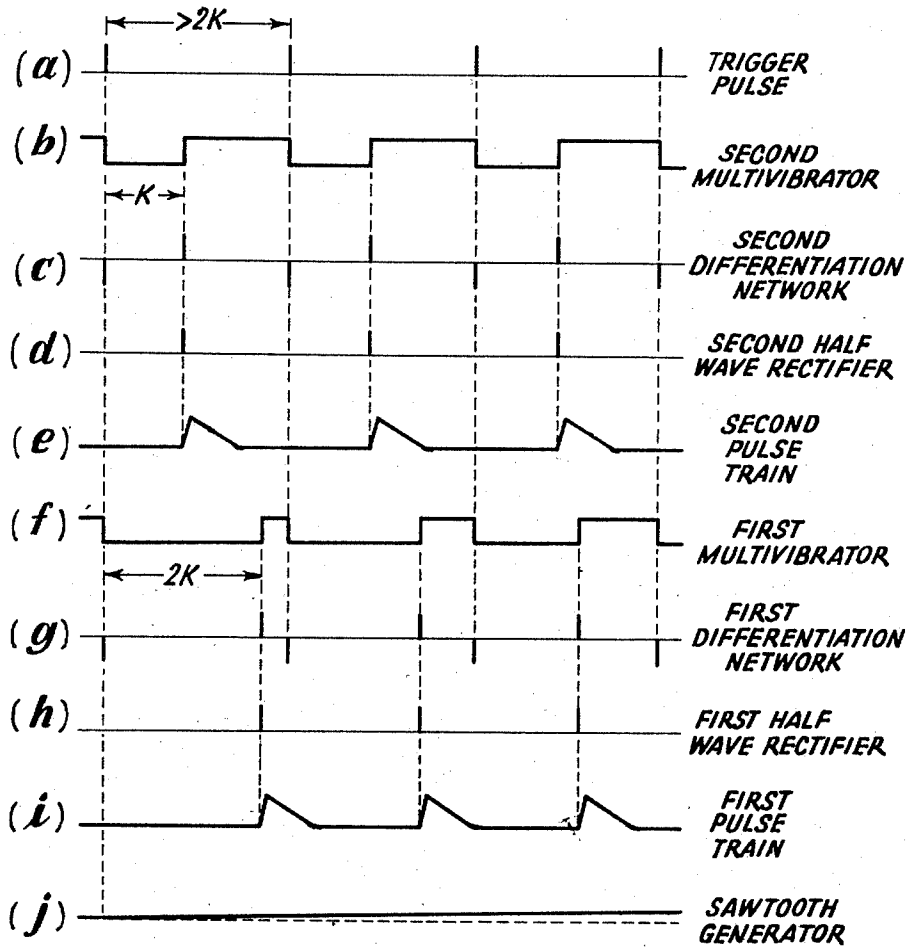
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Fig. 3



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2,917,669

ELECTROLUMINESCENT DEVICE

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Application December 31, 1958, Serial No. 784,212

12 Claims. (Cl. 315—174)

My invention is directed toward electroluminescent devices.

In my copending application, Serial No. 776,980 filed November 28, 1958 (Docket #8468), I disclosed a new type of electroluminescent device wherein, in response to an incoming voltage pulse, a spot of light was caused to travel across (or scan) an electroluminescent layer.

As explained in more detail in this application, this device includes a strip of crystalline piezoelectric material. First and second contacts, positioned opposite each other, are secured to opposite surfaces of this strip adjacent one end thereof. An electroluminescent layer is placed in intimate engagement with one surface of the strip intermediate the appropriate contact and the other end of the strip. A voltage pulse is applied between the contacts. This pulse produces, in the region of the strip between the contacts, a mechanical strain proportional to the amplitude of the pulse. As this strain changes, a disturbance, in the form of an elastic wave accompanied by an electric field, propagates along the strip from the contacts toward the other end of the strip.

As the elastic wave propagates along the strip, the accompanying electric field produces a spot of light in the electroluminescent layer which moves in synchronism with the wave, thus producing an effect similar to a line scanning operation in a cathode ray tube.

As further described in the aforesaid application, a transparent electrode is applied over the exposed surface of the electroluminescent layer and another electrode is applied to the surface of the strip remote from the electroluminescent layer. Application of a modulating voltage between these electrodes modulates the light intensity of the travelling spot accordingly.

In the above described invention, the period of time (or scanning interval) required for the spot of light to traverse the strip is determined both by the velocity of progagation of the elastic wave within the strip, and the length of the section of the strip between the contacts and the other end of the strip. Further, the control pulse and the modulating voltage have separate functions and must be separately applied to the strip.

It is an object of the present invention to eliminate the interdependence of the scanning interval and the velocity of propagation of an elastic wave in an electroluminescent device of the character described.

Another object is to combine the scanning and modulating functions in an electroluminescent device of the character described.

Still another object is to provide a new and improved electroluminescent device wherein the same control pulses not only establish the velocity of scanning but also produce modulation of the travelling spot of light.

In accordance with the principles of my invention, first and second contacts are respectively secured to opposite surfaces of a strip of crystalline, piezoelectric material adjacent one end thereof and thus subtend a first section of the strip. Further, third and fourth contacts are respectively secured to the front and rear surfaces

of the strip adjacent the other end of the strip and thus subtend a second section of the strip.

The ends of the strip are terminated in such manner as to absorb, substantially without reflection, any incident elastic wave supplied thereto from said strip. An electroluminescent layer is placed in intimate engagement with the front surface of the strip in a position intermediate the appropriate contacts.

First and second control voltage pulses are applied between the first and second contact pair and the third and fourth contact pair respectively. Each of these pulses produces, in the corresponding first or second section of the strip, a mechanical strain proportional to the amplitude of the pulse. As this strain changes, a disturbance in the form of an elastic wave accompanied by an electric field, propagates along the strip from the appropriate section towards the other end of the strip where it is absorbed substantially without reflection. More particularly, the first pulse produces in the first section of the strip, a first elastic wave, accompanied by a first electric field, which propagates from the first section toward the second section of the strip. Similarly, the second pulse produces, in the second region, a second elastic wave, accompanied by a second electric field, which propagates from the second section toward the first section. The intensity of each electric field is proportional to the time rate of change of the strain which produced it; stated differently, the intensities of the first and second electric fields are respectively proportional to the first time derivatives of the corresponding first and second pulses.

The intensities of the first and second electric fields are additive at the point of intersection of the corresponding elastic waves; the resultant total electrical field intensity at this point produces in the elecroluminescent layer a spot of light at a position coinciding with this point of intersection. The amount of light emitted from this spot is determined by the total field intensity and increases monotonically therewith.

The position of the spot of light depends upon the relative timing of the first and second pulses. For example, when the first and second pulses arrive in time synchronism at the corresponding contact pairs, the light spot will be positioned midway therebetween. Further, the light spot can be moved from this midpoint toward one or the other end of the strip as the first pulse leads or lags the second pulse, the amount of movement depending upon the actual time separation between these pulses.

Consequently, by continuously varying the relative timing of the first and second pulses, the spot of light will "scan" the strip at a velocity dependent upon the rate of timing variation. Further, the light intensity of this spot can be varied by varying the amplitude of these pulses.

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 block diagram of an electronic system wherein the relative timing and amplitudes of the first and second pulses can be varied as required for the device of Fig. 1; and

Figs. 3*a*–3*j* show the waveforms of signals utilized in the system of Fig. 2.

Referring now to Fig. 1, there is shown a thin strip of ribbon **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 contacts **12** and **14** which extend transversely to the long axis of the strip are secured to opposite surfaces

of the strip adjacent the left end thereof; these contacts are positioned opposite each other and subtend a first section **16** of the strip. Similarly, third and fourth transverse contacts **18** and **20** are secured to opposite surfaces of the strip adjacent the right end thereof and subtend a second region **22** of the strip. An electroluminescent layer **24** is placed in intimate contact with one surface of strip **10** intermediate the ends thereof and spaced apart from the contacts **12** and **18**.

Each end of the strip, as explained in more detail in the aforementioned copending application Serial No. 776,980, is terminated in such manner as to absorb, substantially without reflection, any incident elastic wave propagating in said strip. This is accomplished by coating the ends and immediately adjacent portions of strip **10** with a material, such as lead, to provide terminations **30** and **32**.

First and second control voltage pulses are applied between contacts **12** and **14** and contacts **18** and **20**, respectively. Each pulse establishes a corresponding electric field within an appropriate one of sections **16** and **20**. 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 **16** or **20**, a mechanical strain proportional to the instantaneous field intensity. Hence, this strain is proportional to the instantaneous value of the control 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 control pulse. This disturbance propagates along the strip in the form of oppositely directed elastic waves travelling toward the right hand and left hand respectively of strip **10**.

More particularly, the first pulse produces a first elastic wave which travels from section **16** toward the right hand end of the strip. (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 section **20** toward the left hand end of the strip. (The second pulse also produces an oppositely directed wave which is absorbed in termination **32**.)

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 intensities of both fields are additive at the point of intersection of the first and second waves. Consequently, a spot of light is produced in the electroluminescent layer 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. (Each of the first and second travelling electric fields also tends to produce a moving spot of light in the manner described in the aforementioned copending application. However, these effects can be ignored; the non-linear voltage-brightness characteristic of electroluminescent 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.)

When the first and second voltage pulses arrive in time synchronism at the corresponding contact pairs, the point of intersection of the first and second waves will be at the midpoint between the contact pairs. When the first pulse leads the second pulse, the point of intersection will be displaced to the right of the midpoint; when the second pulse leads the first pulse, the point of intersection will be displaced to the left of the midpoint.

More particularly, the time interval required for the elastic wave to traverse that segment of strip **10** in contact with the electroluminescent layer **24** is normally some constant K. When substantially identical first and second pulses are supplied to the corresponding contact pairs at the same time t_0, the corresponding first and second waves will intersect at the midpoint of layer **24** at time $t_0+K/2$. When the second pulse is supplied at time t_0, while the first pulse is supplied at time t_0+K, the waves will intersect at time t_0+K, and the point of intersection will be immediately adjacent contact **12**. On the other hand, when the second pulse is supplied at time t_0, while the first pulse is supplied at time t_0-K, the waves will intersect at time t_0, and the point of intersection will be immediately adjacent contact **18**.

In this manner, the spot of light can be produced in any desired horizontal position along the electroluminescent layer. Further, the spot can be moved in successive positions from the extreme left hand to the extreme right hand edges of the electroluminescent layer **24**, thus producing the desired scanning action.

The scanning action can be carried out in the following manner. A first pulse train containing x separate first control pulses (where x is the number of different positions assumed by the spot of light in traversing the length of the electroluminescent layer) is applied between contacts **12** and **14**. The first control pulses are generated at a fixed recurrence frequency; i.e. these first pulses are equidistantly spaced in time. A second pulse train containing 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. The resulting relationship for the first and second pulse trains is shown graphically in Figs. 3*e* and 3*i*.

It is desired that the electroluminescent layer be excited by sharp spike-like pulses. Due to the differentiating action of the strip **10**, the pulses in both trains must have the sawtooth waveform shown 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 ½K 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 contacts can successively intersect with waves produced by two or more pulses applied to the other set of contacts. Under these conditions, several spots of light can be present at different positions on the strip.

A block diagram of circuitry for accomplishing the scanning operation is shown in Fig. 2. (The circuitry designated by each block in this diagram is conventional and will not be shown here.)

A pulse train containing x separate, equidistantly spaced timing or trigger pulses is supplied to the inputs of a first single shot multivibrator **102** and a second single shot multivibrator **104**. (The time spacing between adjacent trigger pulses is slightly greater than 2K or in other words, the recurrence frequency of the trigger pulses is slightly less than ½K.) The output signal yielded by the first multivibrator **102** passes successively through a first differentiation network **106** and a first half wave rectifier **108** to the input of pentode tube **110**. The output circuit of tube **119** is coupled between contacts **12** and **14** of strip **10** of Fig. 1. The resultant signals supplied to the strip **10** from tube **110** form a pulse train of x separate first control pulses having a sawtooth waveform.

Similarly, the output signal yielded by the second multivibrator **102** passes successively through a second differentiation network **112** and a second half wave rectifier

114 to the input of pentode tube 116. The output circuit of tube 116 is coupled between contacts 18 and 20 of strip 10 of Fig. 1. The resultant signals supplied to the strip 10 from tube 116 form a pulse train of x separate second control pulses having a sawtooth waveform.

The trigger pulses are also supplied through a frequency divider 122 to the input of a sawtooth generator 100. Divider 122 produces one sharp divider pulse for every group of x trigger pulses supplied to the divider input. More particularly, the divider produces an output pulse for each incoming $(mx+1)$ trigger pulse where m is any integer or 0 and x has been defined previously. Each divider pulse actuates the generator 100 which thereupon yields an output voltage having a sawtooth waveform. This voltage increases positively from 0, the period of the sawtooth being $2\times K$.

The second multivibrator has a fixed period equal to the interval K. The first multivibrator has a variable period falling within the range $0-2K$. The length of this variable period is determined by a control voltage supplied to a control input 120 of the first multivibrator 102 from the output of sawtooth generator 100.

The operation of the system of Fig. 2 will now be described with reference to the waveforms shown in Fig. 3. These waveforms show a portion of the pulse sequence.

The trigger pulses (Fig. 3*a*) are supplied to the input of the second multivibrator 102. Upon the arrival of each trigger pulse, the second multivibrator produces a rectangular shaped pulse (Fig. 3*b*) having a fixed period K. This fixed period pulse is differentiated in the second differentiation network 112 to produce alternatively positive and negative pulses (Fig. 3*c*). These positive and negative going pulses are supplied to the second half wave rectifier (114) which permits only the positive pulses to pass therethrough (Fig. 3*d*). These positive pulses then pass through tube 116 and appear across contacts 18 and 20 of strip 10 of Fig. 1 as a pulse train of x separate, equidistantly spaced second control pulses (Fig. 3*e*). (The two contacts 18 and 20 together with the section 22 of strip 10 constitute a capacitor. The combination of this capacitor and the resistor in the plate circuit of tube 116 acts upon the pulses passing through tube 116 to change their waveform from a spike to a sawtooth. As previously indicated, this waveform conversion is required because of the differentiating action of the strip 10.)

The trigger pulses are also supplied through the divider 122 to the input of the sawtooth generator 100 which thereupon produces an output voltage having a sawtooth waveform (Fig. 3*j*) in the manner previously described.

Further, the trigger pulses are supplied to the input of the first multivibrator 104. Upon the arrival of each trigger pulse, the first multivibrator produces a rectangular shaped pulse (Fig. 3*f*) having a period which decreases from 2K to almost 0 in accordance with the changing sawtooth voltage developed by generator 100 and supplied as a control input to the first multivibrator 104.

This rectangular pulse of variable period is then differentiated (Fig. 3*g*); the positive pulses yielded upon differentiation pass through the second half wave rectifier (Fig. 3*h*) and are supplied to the input of tube 110. The pulses developed in the output of tube 110 and thereafter applied between contacts 12 and 14 of strip 10 of Fig. 1 thus constitute a pulse train of x separate first control pulses having a sawtooth waveform (Fig. 3*i*), the time spacing between corresponding pulses in the two control pulse trains being variable.

The peak amplitudes of both first and second control pulses are increased or decreased in accordance with the amplitude variations of a modulation voltage supplied in time coincidence to the inputs of both of tubes 110 and 116.

In this manner. a spot of light is caused to traverse the electroluminescent layer, the intensity of the light spot and the velocity of travel of the spot being determined by the amplitude and relative timing of control pulses.

What is claimed is:

1. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other: third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; and an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts.

2. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; and first and second terminations affixed to corresponding ends of said strip, said terminations absorbing substantially without reflection any incident elastc wave supplied thereto from said strip.

3. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagementt with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; first and second terminations affixed to corresponding ends of said strip, said terminations absorbing substantially without reflecton any incident elastic wave supplied thereto from said strip; means to apply first voltage pulses between said first and second contacts, each first pulse producing a first elastic wave and an accompanying first electric field which propagate along said strip toward said third and fourth contacts; means to apply second voltage pulses between said third and fourth contacts, each second pulse producing a second elastic wave and an accompanying second electric field which propagate along said strip towards the first and second contacts, a spot of light being generated in said layer at the point of intersection of said first and second waves.

4. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; first and second terminations affixed to corresponding ends of said strip, said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said strip; means to apply first voltage pulses between said first and second contacts, each first pulse producing a first elastic wave and an accompanying first electric field which propagate along said strip toward said third and fourth contacts; means to apply second voltage pulses between said third and fourth contacts, each second pulse producing a second elastic wave and an accompanying second electric field which propagate along said strip toward the first and second contacts, a spot of

light being generated in said layer at the point of intersection of said first and second waves, and means to vary the amplitude of said first and second pulses whereby the light emitted from said spot is modulated accordingly.

5. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; first and second terminations affixed to corresponding ends of said strip, said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said strip; means to apply first voltage pulses between said first and second contacts, each first pulse producing a first elastic wave and an accompanying first electric field which propagate along said strip toward said third and fourth contacts; means to apply second voltage pulses between said thrid and fourth contacts, each second pulse producing a second elastic wave and an accompanying second electric field which propagate along said strip toward the first and second contacts, a spot of light being generated in said layer at the point of intersection of said first and second waves, and means to vary the relative timing between successive first pulses and corresponding successive second pulses to shift the point of intersection of said waves accordingly.

6. An electroluminescent device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; first and second terminations affixed to corresponding ends of said strip, said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said strip; means to apply a first voltage pulse between said first and second contacts to produce a first elastic wave and an accompanying first electric field which propagate along the strip toward said third and fourth contacts; means to apply a second voltage pulse between said third and fourth contacts to produce a second elastic wave and an accompanying second electric field which propagate along the strip toward said first and second contacts, each of said waves traversing the entire length of said strip in a constant time period K, a spot of light being generated in said layer at the point of intersection of said waves, the light intensity varying monotonically with the summation of the first and second electric field intensities; and means to vary the relative timing of one of said pulses with respect to the other from time $-K$ to time $+K$, the position of said point of intersection being shifted horizontally along said layer in accordance with said relative timing.

7. A device as set forth in claim 6 including means to amplitude modulate said pulses, the electric field intensities varying monotonically in accordance with the pulse amplitudes.

8. An electroluminescent device responsive to a first pulse train containing x separate equidistantly spaced trigger pulses and comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; an electroluminescent layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts; first and second terminations affixed to corresponding ends of said strip; said terminations absorbing substantially without reflection any incident elastic wave supplied thereto from said strip; first means responsive to said trigger pulses to derive therefrom a second pulse train of x different equidistantly spaced sawtooth pulses, said second pulse train being applied between said first and second contacts; and second means responsive to said trigger pulses to derive therefrom a third pulse train of x different sawtooth pulses, said third pulse train being applied between said third and fourth contacts, each sawtooth pulse producing in said strip an elastic wave which propagates the entire length of said strip in a constant time period K; and third means coupled to said second means and responsive to said trigger pulses to successively vary the relative timing of each Nth pulse in said third train with respect to the corresponding Nth pulse in said second train (where N is any integer from 1 to x) from time $+K$ to time $-K$.

9. A device as set forth in claim 8 wherein the recurrence frequency of said first pulse train does not exceed the quantity $\frac{1}{2}K$ where the frequency is expressed in cycles per second and K is expressed in seconds.

10. A device as set forth in claim 8 wherein the recurrence frequency of said first pulse train does not exceed the quantity $\frac{1}{2}K$ where the frequency is expressed in cycles per second and K is expressed in seconds and wherein said third means includes a sawtooth generator rendered operative upon the arrival of the first trigger pulse, the period of said generator being $2 \times K$.

11. A device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; and an electric field responsive layer placed in intimate engagement with one of said surfaces intermediate the ends of the strip and spaced apart from said contacts.

12. A device comprising a strip of piezoelectric material; first and second contacts secured to opposite surfaces of said strip adjacent one end thereof, said first and second contacts being positioned opposite each other; third and fourth contacts secured to said opposite surfaces adjacent the other end of said strip, said third and fourth contacts being positioned opposite each other; first means to apply a first voltage pulse between said first and second contacts to produce a first elastic wave and an accompanying first electric field which propagate along said strip toward said third and fourth contacts; second means to apply a second voltage pulse between said third and fourth contacts to produce a second elastic wave and an accompanying second electric field which propagate along said strip toward said first and second contacts; and third means positioned adjacent said strip and responsive to said first and second electric fields.

No references cited.