

Dec. 8, 1959

B. ROSENBERG
ELECTROLUMINESCENT DEVICE

2,916,630

Filed Nov. 28, 1958

2 Sheets-Sheet 1

FIG. 1.

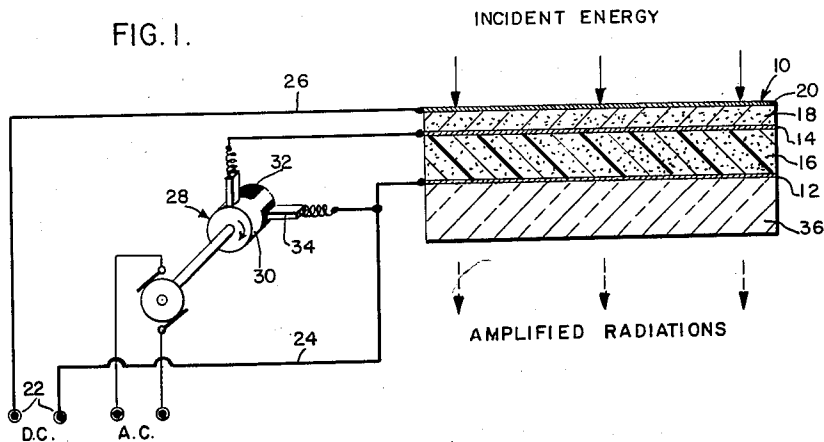


FIG. 3.

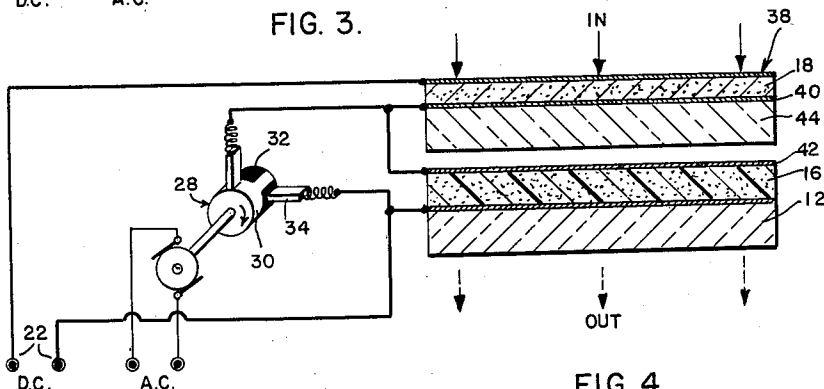


FIG. 2.

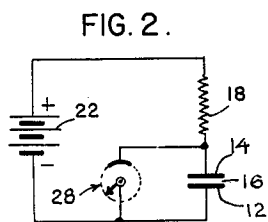


FIG. 4.

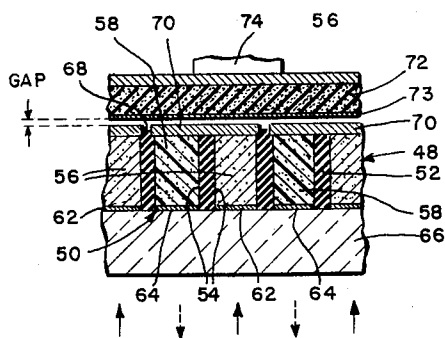
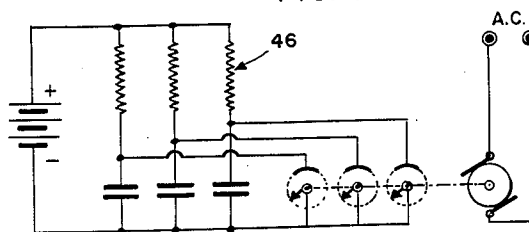


FIG. 6.

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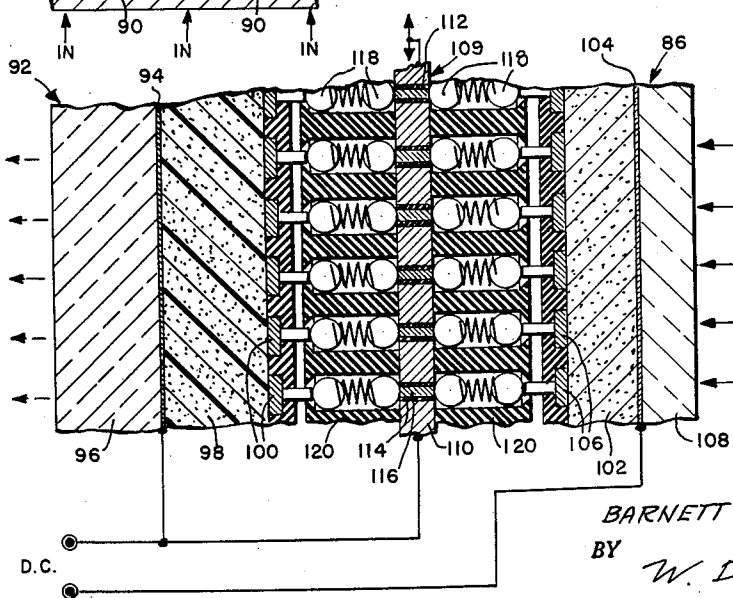
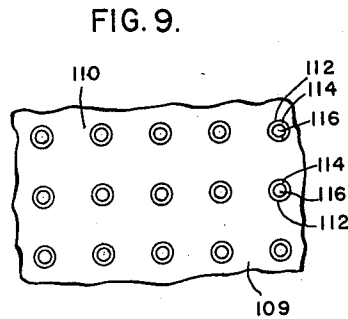
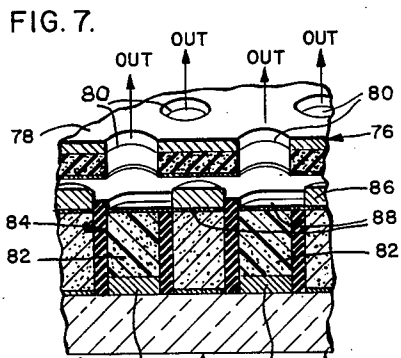
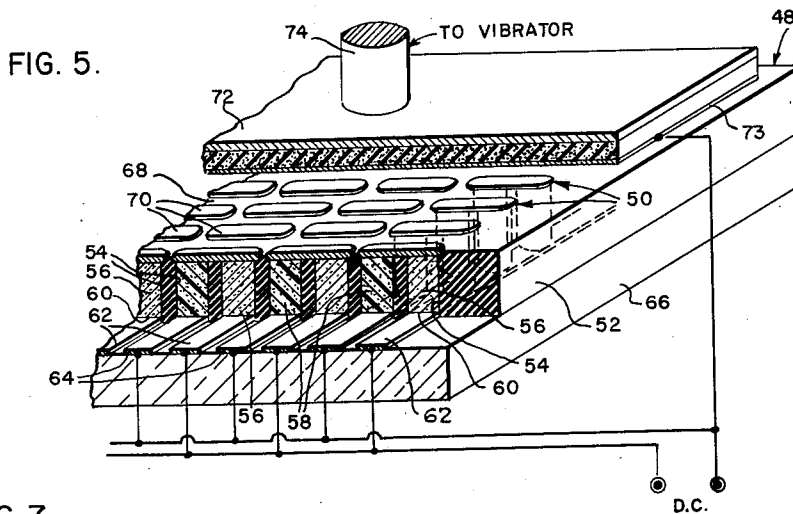
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2 Sheets-Sheet 2



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ELECTROLUMINESCENT DEVICE

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Application November 28, 1958, Serial No. 776,817

13 Claims. (Cl. 250—213)

This invention relates to electroluminescent devices and, more particularly, to energy- and image-amplifying devices having fast response and a high degree of sensitivity.

Energy- and image-amplifying devices comprising photoconductor material and electroluminescent phosphor combinations are well known and are generally described in U.S. Patent No. 2,650,310, dated August 25, 1953. Such devices as described in the above-mentioned patent comprise a layer or stratum of photoconductor material and a separate layer or stratum of electroluminescent phosphor material, which separate layers are sandwiched together between two electrodes. When an A.C. potential is applied across the electrodes and the photoconductor material, or a portion thereof, is irradiated with some sort of external energy, such as X-rays or light for example, the electrical impedance of the photoconductor stratum decreases at that portion which is irradiated. This in turn places the alternating electric field across the electroluminescent phosphor layer per se rather than the combined phosphor-photoconductor layer, thereby causing the phosphor to emit light because of the increased field. With such a device, the photoconductor layer can be represented as a parallel-connected resistance and capacitance. The electroluminescent layer can also be represented as a parallel-connected resistance and capacitance. Both of these parallel-connected R.C. circuits are connected in series across the source of energizing A.C. potential. When the photoconductor is not irradiated or otherwise energized, the resistances of both the photoconductor and the electroluminescent layer are quite high. In order that most of the energizing potential is applied across the photoconductor under so-called "dark" conditions, the capacitance of the photoconductor must be small as compared to the capacitance of the electroluminescent portion of the device. This in turn requires that thickness of the photoconductor be made great as compared to the thickness of the electroluminescent phosphor layer. A thick photoconductor layer, however, impairs resolution and sensitivity and in addition, the most sensitive photoconductor materials are quite slow in response.

It is the general object of this invention to avoid and overcome the foregoing and other difficulties of and objections to prior-art practices by the provision of an energy-amplifying device which is extremely sensitive.

It is another object to provide an element for an image-amplifying device as well as an image-amplifying device which is extremely sensitive and can be made to operate with good resolution.

It is a further object to provide an energy- or image-amplifying device which can utilize comparatively-thin photoconductor layers which are fast in response and are very sensitive to excitation.

It is an additional object to provide various embodiments and constructional details for energy-amplifying and image-amplifying devices.

The aforesaid objects of the invention, and other

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objects which will become apparent as the description proceeds, are achieved by placing a stratum comprising electroluminescent phosphor between two electrodes. An additional stratum comprising photoconductor material is also placed between two electrodes. One of each of the electrodes bounding the separate strata can be made common if desired or four separate electrodes can be used with a direct electrical connection between two of them. The outermost electrodes bounding the separate strata, which electrodes are not directly electrically connected to one another, are adapted to be connected across a source of D.C. potential. The remaining electrode or electrodes are adapted to be commutated in an alternating and rapid fashion in order alternately and rapidly to place such electrode or electrodes at a potential level which at least approaches the potential level of the outermost uncommutated electrode which is adjacent to the electroluminescent phosphor. This allows the device to operate from D.C. potential excitation with a storage-type operation and capacitive effects of the photoconductor stratum and electrodes associated with same are minimized. The result is that the device can be made extremely sensitive with respect to amplifying energy and energy-images and fast-response photoconductor materials can be used in very thin layers if desired.

For a better understanding of the invention reference should be had to the accompanying drawings wherein:

Fig. 1 is a sectional elevation of an energy-amplifying device with the commutator means therefor shown in perspective view;

Fig. 2 is a diagrammatic representation of the embodiment as shown in Fig. 1;

Fig. 3 is an alternative embodiment of the device as shown in Fig. 1 wherein the phosphor and photoconductor strata are formed with an appreciable spacing therebetween;

Fig. 4 is a diagrammatic representation of a multi-element device which can operate as an image amplifier;

Fig. 5 is a fragmentary, enlarged perspective view, partly in section, of one embodiment of an image-amplifying device;

Fig. 6 is a fragmentary sectional enlargement of a portion of the device as shown in Fig. 5, further illustrating constructional details therefor;

Fig. 7 is a fragmentary, enlarged perspective view, shown partly in section, illustrating an alternative embodiment of the device as shown in Figs. 5 and 6;

Fig. 8 is an alternative embodiment of an image-amplifying device wherein the photoconductor and electroluminescent phosphor strata are considerably spaced from one another, with a commutating mechanism interposed therebetween;

Fig. 9 is a fragmentary front elevation of the contact plate used to commutate the individual amplifying elements comprising the device as shown in Fig. 8.

With specific reference to the form of the invention shown in the drawings, the numeral 10 in Fig. 1 illustrates an energy-amplifying device which can also be used as one element of an image-amplifying device. The device 10 generally comprises a first electrode 12 which is transmissive to the energy-amplified radiation to be presented by the device, a second electrode 14 and a stratum 16 comprising electroluminescent phosphor sandwiched therebetween. Adjacent to the electrode 14 is a stratum 18 at least principally comprising photoconductor material, which material is selected to vary inversely in electrical resistance with the intensity of energy which is to be received by the device 10. In the device embodiment as shown, the stratum 18 is surrounded by a pair of electrodes, one of such pair being the electrode 14 which also acts to energize the stratum 16 comprising electroluminescent phosphor. An addi-

tional electrode 20 is placed on the other side of the stratum 18 and this electrode 20 is transmissive to the energy which is to be received by the device 10. The area of each of the electrodes can vary considerably. In the case of a single-unit energy-amplifying device, each electrode can have an area of from one square inch to one square foot for example. In the case of an image-amplifying device, the effective area of the electrodes will usually be made considerably smaller. A D.C. potential source 22 is connected to the electrodes 12 and 20 by means of lead conductors 24 and 26 respectively. A motor driven commutator 28 electrically connects between the electrodes 12 and 14 in order alternately and rapidly to place the electrode 14 at a potential level which at least approaches the potential level of the electrode 12. The commutator 28 comprises a metallic rotatable drum 30 carrying thereon an insulating section 32. When the brush 34 is in direct contact with the conducting metallic drum 30, any D.C. potential which has accumulated on the electrode 14 is rapidly dissipated. The D.C. source 22 can deliver a potential of 100 volts for example.

The device 10 as shown in Fig. 1 can be constructed to amplify any energy which can be propagated through vacuum such as X-rays, ultraviolet radiations, visible light, infrared radiations or cathode rays. This energy is converted into energy-amplified radiations, which will normally take the form of visible light. A diagrammatic representation of the device illustrated in Fig. 1 is shown in Fig. 2. The photoconductor stratum 18 is represented as a resistance which is quite high when the photoconductor stratum is not energized and which varies inversely with the intensity of the energy to be received by the device 10. In other words, the stronger the exciting energy signal, the lower the resistance of the photoconductor stratum 18. A lowered resistance of the photoconductor stratum 18 allows one side of the capacitor formed by the electroluminescent stratum 16 and the bounding electrodes 12 and 14 to charge, with the rate of charging being determined by the intensity of the received energy. After a predetermined period, which can be $\frac{1}{60}$ second for example, the commutator 28 has rotated sufficiently to place the electrode 14 at substantially the same potential level as the electrode 12. This sudden dissipation of charge causes the electroluminescent cell which is formed by the electrodes 12 and 14 and the phosphor stratum 16 to emit a sudden flash of light, the intensity of which varies with the amount of charge dissipated. The device 10 thus operates on the principle that a D.C. charge is accumulated and then is suddenly discharged and the resulting change in electric field across the electroluminescent phosphor causes same to emit light. Since the capacitive effects of the photoconductor and its bounding electrodes are minimized by this arrangement, the photoconductor stratum 18 can be made as thin as desired and in addition, extremely fast photoconductor materials can be used, since even relatively insensitive photoconductor materials when used in thin layers have a high effective sensitivity with respect to exciting energy.

As a specific example, the electrode 12 can be formed of light-transmitting tin oxide deposited onto a glass supporting plate 36. The electroluminescent stratum 16 can comprise an electroluminescent phosphor such as zinc sulfide activated by copper and coactivated by chlorine and such phosphors are well known. Desirably the phosphor is embedded throughout a dielectric material, such as by embedding the finely-divided phosphor in an equal amount by weight of dielectric material. With such a construction the dielectric material should be light transmitting and polyvinyl-chloride acetate or other conventional plastic or ceramic dielectric material is suitable, as is well known. If desired an additional layer of dielectric can be included between the electrodes 12 and 14 or separate layers of phosphor and

dielectric material can be included between the electrodes 12 and 14. Such constructions are conventional in the electroluminescent art. The electrode 14 can be formed of vacuum-metallized aluminum or it can be formed of copper iodide for example. If the energy which is to be amplified comprises visible light or energy which is capable of exciting the electroluminescent phosphor to visible luminescence, the electrode 14 can be formed of a material which is not transmissive to visible light or to the energy which is to be amplified. As an example, if ultraviolet or visible radiations are to be amplified, the electrode 14 can be formed of vacuum-metallized aluminum deposited as an opaque layer and if cathode rays are to be amplified, an additional layer of glass can also be included adjacent the electrode 14. The thickness of the phosphor-dielectric layer 16 is in no way critical and as an example is one mil. The electroluminescent phosphor can also be included between the electrodes 12 and 14 with no admixed or separate dielectric or the phosphor can be utilized in the form of a thin film, such thin films of phosphor being generally described in Feldman and O'Hara article appearing in "Journal of the Optical Society of America," vol. 47, No. 4, pages 300-305 (April 1957).

The photoconductor stratum 18 can be formed of various materials depending upon the energy which is to be amplified. As an example, the photoconductor stratum 18 can be formed of powdered cadmium sulfide, which if desired can have admixed therewith a small amount of dielectric material such as 5% by weight. The admixed dielectric, if used, can be similar to the dielectric used with the phosphor, but the amount should be limited so that the stratum 18 can when excited conduct D.C. Powdered cadmium sulfide varies in resistance under irradiation by longer wavelength visible radiations or X-rays. Cadmium selenide and cadmium telluride can be substituted for the cadmium sulfide and are also similar in response. Powdered zinc-cadmium sulfide is not as sensitive a photoconductor as cadmium sulfide per se, but can be made broadly responsive to different wavelengths by varying the zinc to cadmium ratio, as is well known, and such a photoconductor can respond to a broad range extending from 3650 A.U. to 7000 A.U., as well as to X-rays. Lead sulfide is sensitive to infrared radiations. The foregoing inorganic photoconductor substances can also be evaporated as thin continuous films by means of the technique as specified hereinbefore for preparing thin films of zinc sulfide electroluminescent phosphor. These thin films of inorganic photoconductor substances are quite sensitive and are somewhat faster in decay time than the powdered inorganic photoconductor materials. It is also possible to use organic photoconductor substances. Organic photoconductor substances are normally quite fast in response and decay, but are somewhat less sensitive than the powdered inorganic photoconductor substances, although in the present device this is not particularly detrimental since the photoconductor stratum 18 can be made extremely thin in order to enhance the effective sensitivity of the photoconductor material. As an example, anthracene photoconductor material is responsive to ultraviolet radiations to decrease in resistance and under relatively-low-intensity irradiation has a decay time in the order of 0.01 second. Naphthalene is responsive to ultraviolet and to visible radiations up to the yellow portion of the spectrum, which radiations cause this photoconductor to decrease in resistance. Pentacene is responsive to all visible radiations to vary in resistance and is relatively fast in decay time. In the case organic photoconductor substances are utilized, it is necessary that the positive pole of the applied D.C. potential is connected to the electrode which is adjacent the surface of the photoconductor material which is adapted to receive the energy which is to be amplified. In the case of inorganic photoconductor substances, it does not

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usually matter which pole of the applied D.C. potential is connected to the electrode layer adjacent to the photoconductor surface which is to receive the energy to be amplified. It is also possible to sensitize photoconductivity in various photoconductor materials in order to alter the types of radiations to which these photoconductors are responsive. This is accomplished by admixing other materials with the photoconductor substance and such a technique is disclosed in R. G. Nelson article appearing in "Journal of the Optical Society of America," vol. 46, No. 1, pages 13-16 (January 1956). In a device as shown in Figs. 1 and 2, the photoconductor substance need not have a great thickness as compared to the electroluminescent phosphor stratum, as in prior art energy- and image-amplifying devices. This is because the photoconductor substance acts primarily as a valve in order to accumulate a D.C. potential on an electrode which is adjacent to the stratum comprising electroluminescent phosphor. Thus the photoconductor can be made as thin as desired and as an example, can have a thickness of ten microns. This thickness can be varied considerably. The electrode 20 can be formed of copper iodide or of tin oxide formed on an additional glass support (not shown).

In Fig. 3 is shown a device embodiment 38 which generally corresponds to the device embodiment 10 as shown in Fig. 1 except that the electrode members which bound the separate strata comprising photoconductor material 18 and electroluminescent phosphor 16 are physically separated from one another with one of the electrodes 40 bounding the photoconductor material maintained in electrical continuity with one of the electrodes 42 bounding the electroluminescent phosphor. An additional supporting plate glass 44 is provided adjacent the electrode 40, which can be formed of tin oxide for example. The electrode 42 which is electrically connected to the electrode 40 can be formed of vacuum-metallized aluminum for example. Other than these indicated differences, the device 38 can be identical to the device 10 as shown in Fig. 1. With a device of this general description, brightness amplifications of 242 and energy amplifications of 150,000 have been achieved.

The device embodiments 10 and 38 as shown in Figs. 1 and 3 represent either an energy-amplifying device or one element of an image-amplifying device wherein a plurality of such elements are arranged in adjacent relationship in order to present a composite image. An image-amplifying device 46 is represented diagrammatically in Fig. 4, wherein three individual energy-amplifying elements are positioned in adjacent relationship to act as an image amplifier. Each of the individual elements as shown in Fig. 4 can be constructed in accordance with either of the embodiments 10 or 38 as shown in Figs. 1 and 3. In the device embodiment 46, the electrodes which are used with each of the elements comprising the image amplifier are electrically insulated from one another and each has an area corresponding to the degree of resolution which is desired for the image-amplifying device, such as four square mils for example. In some cases, the outermost bounding electrodes can be made continuous in nature, as will be described hereinafter, and in such construction only a small portion of each of the outermost continuous electrodes will cooperate with the very small electrode member oppositely disposed thereto, which small electrode member has an area preselected in accordance with the degree of resolution desired for the device.

In Fig. 5 is shown in perspective view a portion of an image-amplifying device 48 which comprises a plurality of individual energy-amplifying elements 50. The device 48 comprises a foundation layer 52 which can be formed of an opaque, electrically-insulating material such as glass-bonded mica or urea formaldehyde for example, having a plurality of aligned apertures 54 laterally drilled

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therethrough. The thickness of the foundation layer 52 can vary considerably and as an example is 1-2 mils. Photoconductor material 56 is retained in alternate lines of the apertures and electroluminescent phosphor 58 is retained in the remainder to said apertures. Each aperture containing photoconductor material 56 and an adjacent aperture containing electroluminescent phosphor 58 forms one element 50 of the image-amplifying device 48 and the area of each of these elements 50 is preselected in accordance with the degree of resolution desired for the image-amplifying device 48. Each line of photoconductor-filled apertures is electrically connected at one side 60 of the foundation layer 52 by means of first conducting strips 62 of tin oxide for example. Each alternate line of apertures containing electroluminescent phosphor 58 is also electrically connected by second conducting strips 64 of tin oxide for example. Each of these conducting strips 62 and 64 can be formed on a glass plate 66 and are adapted to have a D.C. potential applied thereacross. The other side 68 of the foundation 52 has included thereon a plurality of small conducting segments 70 which serve to connect electrically one side of the photoconductor material 56 with one side of the electroluminescent phosphor 58 of each element 50. These small conducting segments 70 can be formed by vacuum-metallizing aluminum over selected portions of side 68 of the foundation layer 52. Each element 50 comprising the image-amplifying device 48 can be generally similar to the device embodiment 38 shown in Fig. 3. For purposes of commutation, a contact plate 72, which is adapted to reciprocate in a rapid fashion, alternately contacts the conducting segments 70. The contact plate 72 can be formed of metal-backed plastic such as polyethylene terephthalate having a layer 73 of conducting material such as copper affixed to the side thereof which is adapted to contact the segments 70. This conducting layer 73 is electrically connected to the second tin oxide electrode strips 64. When the contact plate 72 is vibrated in a rapid manner to contact the conducting segments 70, this has the effect of placing the conducting segments 70 at the same potential as the second tin oxide conducting strips 64. If the photoconductor material 56 of an element 50 has not been excited with light or other energy to be amplified, no D.C. charge will have accumulated on the conducting member 70 associated with the element. If the photoconductor portion 56 of an element 50 has been irradiated with energy to which it is sensitive, a D.C. charge will have accumulated on the appropriate conducting member 70 in proportion to the amount of light or other energy which excited the photoconductor material. The resulting rapid discharge of all of the accumulated charges will cause the electroluminescent portions of the device to emit flashes of light. With a sufficiently rapid cycling period, such as 60 cycles per second, the eye will blend the resultant flashes together to what appears to be continuous light.

In Fig. 6 is shown an enlarged fragmentary view of one of the energy-amplifying elements 50 of the device 48 as shown in Fig. 5. As shown more clearly in this view, when the radiation which is to be amplified, such as visible light, irradiates the photoconductor substance 56, a charge is accumulated on the conducting member 70. On commutation of the element 70 by vibrating the contact plate 72, the accumulated charge is dissipated in a rapid fashion and the resulting change in electric field across the electroluminescent phosphor portion of the element 50 causes a short flash of light to be emitted, such flash varying in intensity with the magnitude of the accumulated charge which is dissipated. The vibrator for the contact plate 72 can comprise any conventional electrical vibrator which actuates the plate 72 through a conventional connecting shaft 74 affixed to the metal backing of the contact plate 72.

In the embodiment as shown in Figs. 5 and 6, the

exciting energy is adapted to be applied in an incident fashion on one face of the device 48 and the amplified radiation-energy-image is viewed from the same face of the device. For some purposes, it is desirable to present the amplified radiation-energy-image on the face of the device which is opposite to the face of the device which is adapted to receive the energy which is to be amplified. Such an embodiment 76 is shown in Fig. 7. This embodiment generally corresponds to the device embodiment 48 as shown in Fig. 6 except that the reciprocable contact plate 78 is provided with a plurality of apertures 80 which are aligned with the electroluminescent portions 82 of each of the energy amplifying elements 84 which comprise the device 76. This embodiment is further modified in that a raised contacting member 86 is provided to contact electrically the contact plate 78 at the lower extreme of its throw. Each raised contacting member 86 is electrically connected to a transparent conducting segment 88, one each of which covers one side of each of the amplifying elements 84 comprising the device 76. In addition, the conducting strips 90, which are adjacent the electroluminescent portion 82 of each element 84 and through which D.C. energizing potential is applied, not be made radiation or energy-transmitting and can be fabricated of copper strips for example. Other than these indicated differences, the device 76 as shown in Fig. 7 corresponds to the device 48 as shown in Figs. 5 and 6.

As a further alternative device embodiment, the photoconductor and electroluminescent portions of each element comprising an imaging device can be physically separated from one another by any desired distance and such a device embodiment 92 is shown in Fig. 8. This device embodiment comprises a first electrode 94 which is transmissive to the energy-amplified radiations which are to be presented and this electrode can be fabricated of tin oxide on a glass supporting plate 96. Over the first electrode 94 is placed a stratum 98 comprising electroluminescent phosphor, such as described hereinbefore. Over the stratum comprising electroluminescent phosphor is placed a composite electrode 100 comprising a plurality of small electrode segments, each of which has an area corresponding to the degree of resolution desired for the imaging device. The photoconductor portions of the imaging device 92 are similar in construction to the electroluminescent phosphor portion of the device in that the photoconductor material stratum 102 is bounded by a continuous electrode 104 and composite electrode 106. The stratum 102 can be similar to those described hereinbefore. As in the case of the composite electrode 100, the composite electrode 106 is formed as a plurality of small conducting segments each having an area corresponding to the degree of resolution desired for the device. The electrode 104 can be formed of tin oxide on a glass supporting layer 108. Each of the small segments comprising the composite electrodes 100 and 106 can be formed of small copper segments for example, with each small segment electrically insulated from the segment adjacent thereto. The outermost bounding electrodes 94 and 104 are adapted to be connected across a source of D.C. potential. Each individual segment comprising the composite electrode 100 is maintained in electrical continuity with an individual segment comprising the composite electrode 106. In addition a commutating means 109, which can comprise a vibrating contact plate 110, is provided intermediate the electroluminescent and photoconductor portions of the device 92, in order alternately and rapidly to place each segment comprising the composite electrode 100 at a potential level which at least approaches the potential level of the electrode 94. The contact plate 110 is shown in Fig. 9 and comprises a conducting plate member such as copper having a plurality of apertures 112 provided therethrough. Each of the apertures 112 contains an insulating bushing 114 and a center conducting member

116 within the bushing 114. Spring-loaded electrical contacts 118 are laterally reciprocable within electrically-insulating retaining members 120 positioned on either side of contact plate 110. In the operation of the commutating means 109, when the plate 110 is not actuated, one of each of the segments comprising the composite electrode 106 will be maintained in electrical continuity with one of each of the segments comprising the composite electrode 100 through the center conducting members 116 in contact plate 110. When the contact plate 110 is vibrated from the position as illustrated in Fig. 8, the spring-loaded electrical contacts 118 will be placed in direct electrical contact with the body of the contact plate 110, which in turn is electrically connected to the electrode 94. This will place each of the small segments comprising the composite electrodes 100 and 106 at a potential level which is substantially the same as the potential level of the first electrode 94. Vibration of the contact plate can be accomplished by any conventional electrical vibrating or equivalent device. The electromechanical commutation means 109 can be replaced by an electronic commutating means if desired.

Each element of the device embodiment 92 as shown in Fig. 8 generally corresponds to the energy-amplifying device 38 as shown in Fig. 3, except that the outermost bounding electrodes are desirably made continuous in nature from the standpoint of facility of manufacture. The energy which is to be amplified is directed incident to the photoconductor material stratum 102 and the energy-amplified radiations are viewed from the glass supporting plate 96.

In any of the image-amplifying device embodiments as illustrated and described hereinbefore, excellent resolution can be obtained by virtue of the very thin photoconductor layers which can be utilized. In addition, extremely fast photoconductor substances can be utilized while still obtaining a high degree of effective sensitivity, since even relatively-insensitive photoconductor materials display a high effective sensitivity when used in very thin layers.

Any of the foregoing devices as illustrated and described hereinbefore can be used to amplify extremely weak energy or energy-images and to present such energy or energy-images as amplified radiations. For such a use, the devices can be operated so as to accumulate energy over a relatively long period of time and to dissipate such accumulated energy in a rapid fashion to cause the electroluminescent portions of the devices to produce light varying in intensity in proportion to the magnitude of the accumulated charges. For such operation, the commutating mechanisms as disclosed hereinbefore can be slowed down or dispensed with if desired. In the case the commutating mechanisms are dispensed with, a manual switching arrangement can be used to dissipate in a rapid fashion any accumulated charges on the innermost electrode bounding the electroluminescent stratum. The foregoing devices can thus be made to operate on a "one-shot" principle and the resulting energy-amplified radiations can be photographed if desired. In addition, in any of the foregoing device embodiments, the electrodes or electrode segments associated with the photoconductor material need not have the same dimensions as the electrodes or electrode segments associated with the electroluminescent phosphor. The presented radiation energy or energy-image can thus be expanded or decreased considerably with respect to the area of the energy or energy-image to be amplified. As an example, the electrodes or electrode segments associated with the photoconductor material can have an area which is one-tenth the area of the electrodes or electrode segments associated with the electroluminescent phosphor.

It will be recognized that the objects of the invention have been achieved by providing energy-amplifying and image-amplifying devices which are extremely sensi-

tive and which can be made to operate with good resolution. In addition, there have been provided energy- and image-amplifying devices which can utilize comparatively thin photoconductor materials which are very fast in response and are very sensitive to excitation. There have also been provided various embodiments and constructional details for energy-amplifying and image-amplifying devices.

While various embodiments have been illustrated and described hereinbefore, it is to be particularly understood that the invention is not limited thereto or thereby.

I claim:

1. A device for receiving energy which can be propagated through vacuum and presenting such received energy as energy-amplified radiation, said device comprising, a first electrode transmissive to energy-amplified radiation to be presented by said device, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of energy to be received by said device, a pair of electrode members provided on either side of said stratum comprising photoconductor material, one electrode of said pair of electrode members transmissive to energy to be received by said device, the other electrode of said pair of electrode members maintained in electrical continuity with said second electrode, said first electrode and said one of said pair of electrode members adapted to be connected across a source of D.C. potential, and means for rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

2. A device for receiving energy which can be propagated through vacuum and presenting such received energy as energy-amplified radiation, said device comprising, a first electrode transmissive to energy-amplified radiation to be presented by said device, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of energy to be received by said device, a pair of electrode members provided on either side of said stratum comprising photoconductor material, one electrode of said pair of electrode members transmissive to energy to be received by said device, said second electrode forming the other electrode of said pair of electrode members, said first electrode and said one of said pair of electrode members adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

3. A device for receiving energy which can be propagated through vacuum and presenting such received energy as energy-amplified radiation, said device comprising, a first electrode transmissive to energy-amplified radiation to be presented by said device, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of energy to be received by said device, a pair of additional electrode members physically separated from said first and second electrodes and provided on either side of said stratum comprising photoconductor material, one electrode of said pair of additional electrode members transmissive to energy to be received by said device, the other electrode of said pair of additional electrode members maintained in electrical continuity with said second electrode, said first electrode and said one of said pair of additional electrode members adapted to be connected across a source of D.C.

potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

4. An elemental portion of a device for receiving an elemental portion of an image comprised of energy which can be propagated through vacuum and presenting such received energy-image elemental portion as energy-amplified radiation, said device elemental portion comprising, a first electrode transmissive to the energy-amplified radiation to be presented, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy to be received by said device elemental portion, a pair of electrode members provided on opposite sides of said stratum comprising photoconductor material, one electrode of said pair of electrode members adapted to receive incident thereon and transmissive to the energy to be received by said device elemental portion, the other electrode of said pair of electrode members maintained in electrical continuity with said second electrode, said one electrode of said pair of electrode members and said first electrode adapted to be connected across a source of D.C. potential, and means for rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

5. An elemental portion of a device for receiving an elemental portion of an image comprised of energy which can be propagated through vacuum and presenting such received energy-image elemental portion as energy-amplified radiation, said device elemental portion comprising, a first electrode transmissive to the energy-amplified radiation to be presented, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy to be received by said device elemental portion, a pair of electrode members provided on opposite sides of said stratum comprising photoconductor material, one electrode of said pair of electrode members adapted to receive incident thereon and transmissive to the energy to be received by said device elemental portion, said second electrode forming the other electrode of said pair of electrode members, said one electrode of said pair of electrode members and said first electrode adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

6. An elemental portion of a device for receiving an elemental portion of an image comprised of energy which can be propagated through vacuum and presenting such received energy-image elemental portion as energy-amplified radiation, said device elemental portion comprising, a first electrode transmissive to energy-amplified radiation to be presented, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy to be received by said device elemental portion, a pair of additional electrode members physically separated from said first and second electrodes and provided on opposite sides of said stratum comprising photoconductor material, one electrode of said pair of additional electrode members adapted to receive incident thereon and transmissive to the energy to be received by said device elemental portion, the other electrode of said pair of additional electrode members maintained in electrical continuity with said second elec-

trode, said one electrode of said pair of additional electrode members and said first electrode adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

7. An elemental portion of a device for receiving an elemental portion of an image comprised of energy which can be propagated through vacuum and presenting such received energy-image elemental portion as energy-amplified radiation, said device elemental portion comprising, a first electrode transmissive to energy-amplified radiation to be presented, a second electrode, a stratum comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy to be received by said device elemental portion, a pair of electrode members provided on opposite sides of said stratum comprising material, one electrode of said pair of electrode members adapted to receive incident thereon and transmissive to the energy to be received by said device elemental portion, the other electrode of said pair of electrode members maintained in electrical continuity with said second electrode, said one electrode of said pair of electrode members and said first electrode adapted to be connected across a source of D.C. potential, and electrically-actuated make-and-break means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

8. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which correspond to such received energy-images, which device comprises, a first electrode transmissive to amplified radiation images to be presented, a second electrode formed of a plurality of individual small conducting segments electrically insulated from one another and each having an area corresponding to the degree of resolution desired for said device, material comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy comprising energy-images to be received by said device, a pair of electrode members provided on opposite sides of said stratum comprising photoconductor material, one of said pair of electrode members transmissive to energy-images to be received by said device, the other of said pair of electrode members comprising a plurality of individual small conducting segments electrically insulated from one another and each having an area corresponding to the degree of resolution desired for said device, each individual small conducting segment comprising said other of said pair of electrode members electrically connecting to an individual segment comprising said second electrode, said first electrode and said one of said pair of electrode members adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

9. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which correspond to such received energy-images, which device comprises, a first electrode transmissive to amplified radiation images to be presented, a second electrode formed of a plurality of individual small conducting segments electrically insulated from one another and each having an area corresponding to the degree of resolution desired for said device, material comprising electroluminescent

phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy comprising energy-images to be received by said device, a pair of electrode members provided on opposite sides of said stratum comprising photoconductor material, one of said pair of electrode members transmissive to energy-images to be received by said device, said second electrode forming the other electrode of said pair of electrode members, said first electrode and said one of said pair of electrode members adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

10. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which correspond to such received energy-images, which device comprises, a first electrode transmissive to amplified radiation images to be presented, a second electrode formed of a plurality of individual small conducting segments electrically insulated from one another and each having an area corresponding to the degree of resolution desired for said device, material comprising electroluminescent phosphor sandwiched between said first and second electrodes, a stratum comprising photoconductor material, the electrical resistance of said stratum comprising photoconductor material varying inversely with the intensity of the energy comprising energy-images to be received by said device, a pair of additional electrode members physically separated from said first and second electrodes and provided on opposite sides of said stratum comprising photoconductor material, one of said pair of additional electrode members transmissive to energy-images to be received by said device, the other of said pair of additional electrode members comprising a plurality of individual small conducting segments electrically insulated from one another and each having an area corresponding to the degree of resolution desired for said device, each individual small conducting segment comprising said other of said pair of additional electrode members electrically connecting to an individual member comprising said second electrode, said first electrode and said one of said pair of additional electrode members adapted to be connected across a source of D.C. potential, and means for alternately and rapidly placing said second electrode at a potential level at least approaching the potential level of said first electrode.

11. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which correspond to such received energy-images, which device comprises, a foundation layer comprising opaque electrical-insulating material, a plurality of apertures laterally disposed through said foundation layer, substance comprising photoconductor material retained in the portion of said apertures which are alternately disposed with respect to one another, the electrical resistance of said substance comprising photoconductor material varying inversely with the intensity of energy comprising the energy-images to be received by said device, additional substance comprising electroluminescent phosphor retained in the remainder of said apertures, an energy-amplifying element formed by each said aperture containing photoconductor material and one of said apertures positioned adjacent thereto and containing electroluminescent phosphor, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element electrically connected to one another on one side of said foundation layer, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element adapted to have a D.C. potential

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applied thereacross at the other side of said foundation layer, and means for effecting in a rapid manner a substantially equipotential condition across said electroluminescent phosphor of each said energy-amplifying element.

12. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which correspond to such received energy-images, which device comprises, a foundation layer comprising opaque electrical-insulating material, a plurality of apertures laterally disposed through said foundation layer, substance comprising photoconductor material retained in the portion of said apertures which are alternately disposed with respect to one another, the electrical resistance of said substance comprising photoconductor material varying inversely with the intensity of energy comprising the energy-images to be received by said device, additional substance comprising electroluminescent phosphor retained in the remainder of said apertures, an energy-amplifying element formed by each said aperture containing photoconductor material and one of said apertures positioned adjacent thereto and containing electroluminescent phosphor, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element electrically connected to one another on one side of said foundation layer, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element adapted to have a D.C. potential applied thereacross at the other side of said foundation, a conducting vibrator adapted to contact in a rapid and alternating fashion the one side of said foundation layer on which said photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element electrically connect to one another, and said conducting vibrator adapted to have electrical continuity with the pole of the D.C. potential adapted to be applied to said electroluminescent phosphor comprising each said energy-amplifying element.

13. An image-amplifying device for receiving images comprised of energy which can be propagated through vacuum and presenting amplified radiation images which

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correspond to such received energy-images, which device comprises, a foundation layer comprising opaque electrical-insulating material, a plurality of apertures laterally disposed through said foundation layer, substance comprising photoconductor material retained in the portion of said apertures which are alternately disposed with respect to one another, the electrical resistance of said substance comprising photoconductor material varying inversely with the intensity of energy comprising the energy-images to be received by said device, additional substance comprising electroluminescent phosphor retained in the remainder of said apertures, an energy-amplifying element formed by each said aperture containing photoconductor material and one of said apertures positioned adjacent thereto and containing electroluminescent phosphor, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element electrically connected to one another on one side of said foundation layer, the photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element adapted to have a D.C. potential applied thereacross at the other side of said foundation, a conducting vibrator adapted to contact in a rapid and alternating fashion the one side of said foundation layer on which said photoconductor material and electroluminescent phosphor comprising each said energy-amplifying element electrically connect to one another, said conducting vibrator adapted to have electrical continuity with the pole of the D.C. potential adapted to be applied to said electroluminescent phosphor comprising each said energy-amplifying element, and said conducting vibrator being radiation transmitting in locations disposed adjacent to said electroluminescent phosphor of each said energy-amplifying element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,566,349	Mager	Sept. 4, 1951
2,650,310	White	Aug. 25, 1953
2,839,690	Kazan	June 17, 1958
2,873,380	Kazan	Feb. 10, 1959