Nov. 9, 1965 TADAO KOHASHI 3,217,168

PHOTOSENSITIVE SOLID-STATE IMAGE INTENSIFIER

Filed Dec. 14, 1961 2 Sheets-Sheet 1

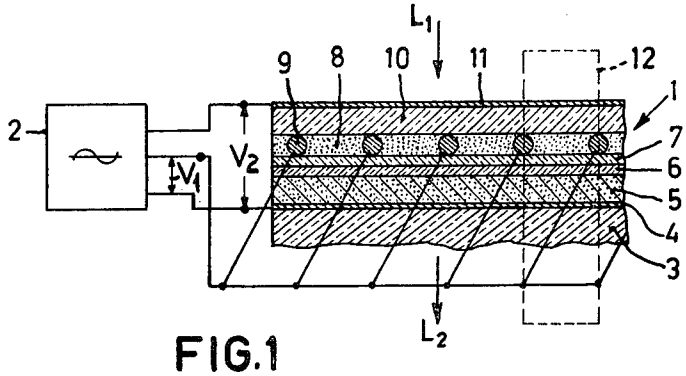


FIG.1

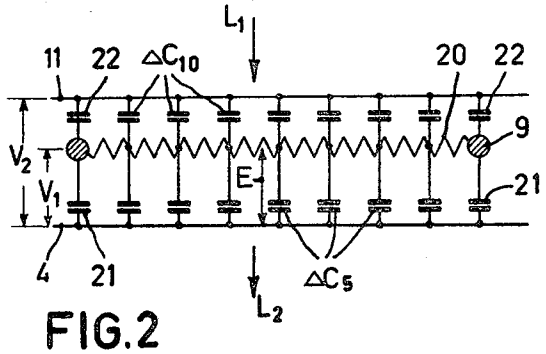


FIG.2

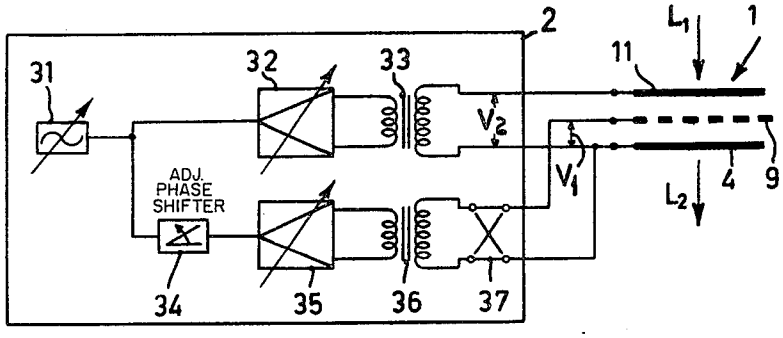


FIG.3

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PHOTOSENSITIVE SOLID-STATE IMAGE INTENSIFIER

Filed Dec. 14, 1961 2 Sheets-Sheet 2

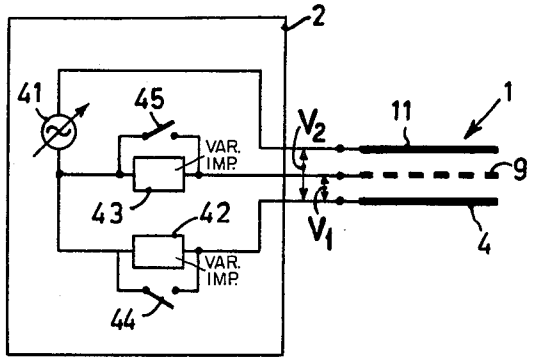


FIG. 4

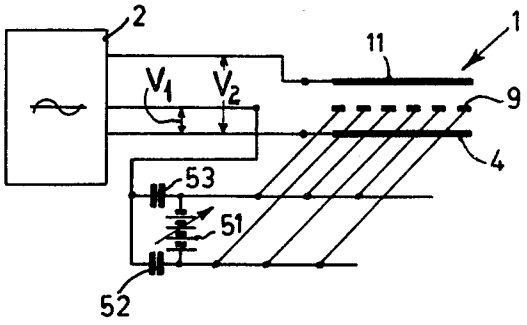


FIG. 5

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PHOTOSENSITIVE SOLID-STATE IMAGE INTENSIFIER

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Claims priority, application Japan, Dec. 29, 1960, 35/51,639
11 Claims. (Cl. 250—213)

This invention relates to a device comprising a solid-state image intensifier connected to a voltage supply apparatus, said intensifier comprising a photo-conductive layer between a luminescent layer having a luminance varying with its electric field intensity and a neutral or fixed impedance layer and also comprising electrodes for applying an electric supply voltage, whereof a first electrode is arranged on the outer side of the luminescent layer and a second electrode is arranged on the outer side of the neutral impedance layer and a third electrode lying between the luminescent layer and the neutral impedance layer consists of electrically interconnected linear, electrically conductive parts, which may be interconnected groupwise and which are in electrical contact with the photo-conductive layer and constitute a line- or net-shaped grid.

A solid-state image intensifier of the kind set forth is described in a prior application of the applicant, Serial No. 109,055, filed May 10, 1961, now Patent No. 3,169,192. The third electrode contacting the photo-conductive layer may consist of a grid of parallel, equidistant, conductive paths, for example of a metal, which are applied to the top face or underneath the photo-conductive layer. Instead of using paths use may be made of metal wires, which are preferably embedded in the photo-conductive layer. These paths or wires may all be connected with each other at the ends, so that they are at the same potential, but they may, as an alternative, be connected alternately with each other, so that two electrical groups of paths or wires are formed. The latter arrangement is used in case it is desired when the intensifier is fed by alternating current to supply the photo-conductive layer with a direct bias voltage with a view to the greater sensitivity of a photo-conductive layer formed by a photo-conductive material and a binder to direct current. This may be achieved by including rectifiers of opposite polarities or direct-voltage sources in the connection of the two groups of the third electrode. The third electrode may furthermore be formed by a net-shaped grid, preferably having square meshes, formed by conductive paths on or below the photo-conductive layer or embedded herein in the form of a net of metal wires.

In the said prior application it has been pointed out that such a solid-state image intensifier is capable of producing a positive or a negative luminescent image of a primary radiation image projected onto the photo-conductive layer according as the supply voltage is fed to the first or to the third electrode, while the second electrode is directly connected to the first electrode or, according as the supply voltage is fed to the first and to the second electrode, while the third electrode is connected directly to the first electrode.

The present invention is based on the recognition of the fact that by varying the relationship between the voltages fed to the second electrode and to the third electrode, with respect to the first electrode, not only a variation of the positive image into the negative image and conversely can be carried out, but also the characteristic curve of the solid-state image intensifier, indicating the relationship between the intensity of the primary

radiation and the resultant luminance of the luminescence image, can be varied within wide limits. This variation applies in particular to the steepness of the said characteristic curve, which determines the gradation of the luminescence image.

The device according to the invention is characterized in that the solid-state image intensifier is connected to the current supply apparatus so that the voltage between the first electrode and the second electrode V_2 and the voltage between the first electrode and the third electrode V_1 differ both from zero and from each other, while provision is made of means for the adjustable variation of the difference between the two voltages (value and/or polarity in the case of direct voltage; amplitude and phase in the case of alternating voltage).

It should be noted that the solid-state image intensifier in the embodiment according to the invention and of the kind described in the aforesaid prior application may be suitable for alternating-voltage supply and also for direct-voltage supply, in which latter case the luminescent layer, the neutral impedance layer and any thin light-screening and/or reflecting layers between the photo-conductive layer and the luminescent layer must have some direct-current conductivity.

In a preferred embodiment of the device according to the invention, the said voltages fed by the supply apparatus to the electrodes of the solid-state image intensifier are such that, in the case of alternating voltages, the phase difference is more than 90° and in the case of direct voltages the polarities are opposite. It is advantageous to choose the voltages so that in the state of minimum conductivity of the photo-conductive layer the voltage between the first and the second electrode V_2 itself and in the state of maximum conductivity of the photo-conductive layer the voltage between the first and the third electrode V_1 itself are capable of exciting the luminescent layer to visible luminance or up to the limit of visible luminance.

In order that the invention may be clearly understood and readily carried into effect, it will now be desired more fully with reference to the accompanying drawing, which shows a few embodiments.

FIG. 1 shows diagrammatically a cross sectional view of a solid-state image intensifier having three electrodes connected to a supply apparatus and

FIG. 2 shows diagrammatically the electric diagram of a group of elements of the solid-state image intensifier shown in FIG. 1, which elements, in common, define an image point of the reproduced image.

FIG. 3 shows the diagram of one embodiment of the supply apparatus shown in the device of FIG. 2, this apparatus being connected to the electrodes of the solid-state image intensifier indicated only by the electrodes and

FIG. 4 shows a different embodiment of the supply apparatus.

FIG. 5 shows a further embodiment of the device according to the invention, in which also the solid-state image intensifier is indicated symbolically only by its electrodes.

In the embodiments shown in the various figures the same parts and elements are found for a large part, particularly with respect to the solid-state image intensifier. These elements or parts are therefore designated in the various figures by the same reference numerals. It should furthermore be noted that various dimensions of the solid-state image intensifier, particularly those referring to the thickness of various layers are not shown with their correct ratio in FIGS. 1 and 2; if necessary suitable numerical values are given for several dimensions hereinafter.

The device according to the invention illustrated in

FIGS. 1 and 2 comprises a solid-state image intensifier **1**, which is connected to a supply apparatus **2** which supplies a voltage which in view of the construction of the solid-state image intensifier to be described is an alternating voltage. The intensifier **1** comprises a number of layers applied one over the other in the following order of succession, viewed from bottom to top: a transparent support **3**, a transparent plane electrode **4**, a luminescent layer **5**, a reflecting layer **6**, a light-screening layer **7**, a photo-conductive layer **8** with an electrode of parallel metal wires **9** embedded therein, a neutral transparent impedance layer **10** and a plane transparent electrode **11**.

The plane electrode **4** (first electrode) may consist of metal applied by vaporisation to the supporting plate **3**, for example gold, or, particularly when the support **3** is formed by a glass plate, of a layer of conductive tin oxide.

The luminescent layer **5**, which has a thickness of, for example, 50μ, may consist of electro-luminescent material, for example zinc sulphide activated by copper and aluminum and a binder, for example an epoxy resin. The thin reflecting layer **6**, which serves to reflect to the optimum the luminescent light produced in the layer **5** towards the supporting plate **3**, may consist of a white reflecting powder, for example barium titanate or titanium dioxide and a binder, which may also be an epoxy resin. This reflecting layer may have a thickness of about 20μ. The opaque layer **7**, which serves to avoid optical feedback due to possible action of luminescent light from the layer **5** on the photo-conductive layer **8**, consists of a binder, for example an epoxy resin, to which carbon powder is added. The composition of this layer must be such that in the direction of the layer substantially no electric conductivity is found. In most cases an addition of 5% by volume of carbon powder to the binder, with a thickness of the layer of about 10μ, will provide an adequate light-screening effect. In order to minimise the impedance in the direction of thickness of this light-screening layer **7**, this layer may contain furthermore a material having a high dielectric constant, for example barium titanate.

The photo-conductive layer **8** consists of a photo-conductive material, for example cadmium sulphide activated by copper and chlorine or cadmium sulphoselenide or cadmium selenide, and a binder, for example an epoxy resin. In this layer **8** are embedded, in parallel position, and at equal distances of 250μ, tungsten wires **9** of a diameter of 10μ. In FIG. 1 the thickness of these wires **9** is shown on an excessive scale. The wires may be located in the central plane of the photo-conductive layer **8**, but it is more advantageous to apply them to the top face of the layer **8**, so that they have an optical screening effect for the parts of the photo-conductive layer **8** lying directly underneath these wires. The wires **9** are electrically connected to each other at one side of the intensifier **1** and constitute together the third electrode of the solid-state image intensifier **1**.

The neutral impedance layer **10**, which may have a thickness of about 70μ, consists of a transparent synthetic resin, preferably having low electric losses and a high dielectric constant, for example an epoxy resin. This layer may, however, consist of glass; it may be formed, for example by a glass foil which is secured to the photo-conductive layer **8** for example by means of a transparent adhesive. The electrode **11** extending over this neutral impedance layer and forming the second electrode of the solid-state image intensifier **1** may consist of a transparent metal layer, applied for example by vaporisation, or of conductive tin oxide. It is not always required for this electrode to be transparent, since if the solid-state image intensifier is to be used with X-rays, the electrode **11** preferably consists of aluminum, having a thickness such that this electrode does not allow visible light to pass.

In accordance with the invention, the supply apparatus **2** is arranged and the electrodes of the solid-state image intensifier **1** are connected to this supply apparatus so that the voltage V_2 between the first and the second electrode and the voltage V_1 between the first and the third electrode both differ from zero and from each other. Since we are concerned in FIG. 1 with a solid-state image intensifier fed by alternating voltage, the later means that the voltages V_1 and V_2 have different amplitudes and/or have a phase difference. The supply apparatus **2** is furthermore arranged so that the difference between the voltages V_1 and V_2 can be varied and be adjusted to a desired value.

The solid-state image intensifier in the device according to the invention is based on the fact that, according as the conductivity of the photo-conductive layer **8** is lower or higher, which conductivity is locally acted upon by a primary radiation image projected through the electrode **11** and the neutral impedance layer **10** onto the photo-conductive layer **8** (this image is symbolically designated in the figures by L_1), the electric field in the luminescent layer **5** resulting from the voltage V_2 between the first and the second electrode (electrodes **4** and **11**) covers larger or smaller regions of this layer respectively, the electric field strength also being increased or decreased respectively, whereas the electric field in the layer **5** due to the voltage V_1 between the first and the third electrode (electrodes **4** and **9**) covers smaller or larger regions of this layer respectively. The operation of the photo-conductive layer may, to some extent, be compared with that of a control-grid in an imaginary electron valve, in which the diameter of the grid wires is varied while the pitch is maintained, this variation in diameter being locally correlated to the local intensity of the primary radiation image L_1.

Referring to FIG. 1, reference numeral **12** designates an elementary cell of the solid-state image intensifier **1**, which cell defines an image point of the image (indicated by the symbol L_2 in the figures), reproduced by the luminescent layer **5** and corresponding to the primary radiation image L_1 projected onto the photoconductive layer **8**. This elementary cell comprises a vertical column of the image intensifier located between two successive wires **9** of the third electrode, which is limited in front of and behind the plane of the drawing in FIG. 1 by vertical planes transversely to the wires **9**, spaced apart by a distance equal to the distance between the successive wires **9**. FIG. 2 shows a largely simplified electric diagram of such an elementary cell of the solid-state image intensifier **1**. The part of the photo-conductive layer **8** in such an elementary cell constitutes a resistance **20** connecting the segments of successive wires **9**, the resistance value in the unexposed state (absence of L_1) being comparatively high and decreasing with an incraesing exposure. Each point of this resistance is capacitatively coupled on the one hand with the electrode **4** and on the other hand with the electrode **11**, with which electrodes also the said segments of the wires **9** are capacitatively coupled. Although we are concerned here with a network having distributed impedances, a non-essential simplification permits of considering this network, as in FIG. 2, as being composed of lumped impedances. In FIG. 2 the capacitors ΔC_{10} represent the capacitative coupling of the parts of the said resistance **20** with the electrode **11**; these capacitors are formed by small vertical columns of the neutral impedance layer **10**. The capacitors ΔC_5 represent the capacitative coupling of the resistance **20** with the electrode **4**; these capacitors are formed by small vertical columns of the luminescent layer **5** and the intermediate layers **6** and **7**. Owing to the small thickness or impedance in the direction of thickness of the two last-mentioned layers the capacitors ΔC_5 are mainly determined by the luminescent layer **5**. The capacitors **21** and **22**, which represent the capacities between the segments of the wires **9** and the electrode **4** and **11** respectively, constitute in fact a non-useful load of the

supply apparatus 2, to which the electrodes of the solid-state image intensifier 1 are connected. The capacity of these capacitors 21 and 22 may be reduced by providing a greater thickness of the layers 5, 6, 7 and 10 at the area of the wires 9 than at the areas between these wires. By arranging the wires 9, if they have a smaller diameter than the thickness of the photo-conductive layer 8, on the top face of the layer 8, it is ensured that the capacity of the capacitors 21 is minimized. Since these contain luminescent material, just these capacitors are the greatest source of disturbances in the reproduced image L_2.

By feeding to the second and the third electrode (electrodes 11 and 9 respectively) by means of the supply appartus, a voltage V_2 and V_1 respectively, with respect to the first electrode (electrode 4), the voltage E across the capacitors ΔC_5, which are connected to points of the resistance 20 lying at a given distance from the wire segments 9, is determined mainly by the distribution of the voltage V_2 across the series-connected capacitors ΔC_{10} and ΔC_5 and is substantially independent of the voltage V_1 in the dark state (absence of L_1), when the value of the resistance 20 is high. However, when the photo-conductive layer 8 is strongly irradiated, so that the value of the resistance 20 becomes very small and hence the element of the photo-conductive layer 8 represented by this resistance may be considered as an equipotential plane being at the potential of the wires 9, all capacitors ΔC_5 have produced across them a voltage which is substantially equal to V_1. When the photo-conductive layer is exposed to a radiation intensity lying between the aforesaid extreme values, the voltage E across the capacitors ΔC_5 will shift constantly farther towards V_1 with an increasing radiation intensity and this first with those capacitors ΔC_5 which are nearest the wire segments 9. This results in that by irradiation of an element of the photo-conductive layer 8 the part of the luminescent layer 5 lying underneath it exhibits a change in the luminance, which may vary between the luminance of the layer 5 at a supply voltage equal to the part of the voltage V_2 obtained across the capacitors ΔC_5 owing to the series combination of the capacitors ΔC_{10} and ΔC_5 and the luminance of the layer 5 with a voltage V_1 over-all the capacitors ΔC_5.

It will now be obvious that by the choice of V_2 and V_1 the characteristic curve of the solid-state image intensifier 1 can be acted upon.

If V_2 and V_1 are in phase and if the amplitude of V_1 evceeds the amplitude of the aforesaid voltage E, obtained by the division of V_2, the image reproduced by the intensifier 1 (image L_2) is a positive image of the primary radiation image L_1. This image L_2 appears on a more or less bright background according as V_2 and hence also E is higher and thereby gives rise, in itself, to a luminance of the layer 5. The contrast in the image L_2 is the greater, the more V_1 exceeds E. By the adjustment of V_2 and V_1 the contrast can thus be adjusted at will, provided the aforesaid conditions are maintained.

If V_2 and V_1 are in phase, but if the amplitude of V_1 is smaller than that of the said voltage E and if the voltage E in itself suffices for exciting the layer 5 to luminesce, the exposure of the photo-conductive layer 8 to a primary radiation image L_1 will produce on the luminescent layer 5 a negative image L_2 or an inverted image i.e. having inverted brightness. The contrast in this negative image is greater according as the amplitudes of V_1 and E are different.

An interesting situation comes up when V_2 and V_1, with respect to the electrode 4 (first electrode) are more or less oppositely directed i.e. have a phase difference of at least 90°, preferably of 180°, while the amplitudes of the voltages V_1 and E are both adequate for exciting alone the luminescent layer 5 to luminesce. A radiation image L_1 projected onto the photo-conductive layer 8 will then be reproduced by the layer 5 partly in the form of a negative image and partly in the form of a positive image. The negative image corresponds to the parts of the primary image L_1 having low radiation intensity, whereas the positive part is obtained from the parts of the primary radiation image of high radiation intensity. The intensity of L_1 with which the negative image changes over to the positive image (transition intensity) depends upon the ratio between E and V_1. The transition intensity is shifted towards lower intensities of L_1 according as E is higher and V_1 is lower and is shifted towards higher intensities of L_1 according as E is lower and V_1 is higher. Since E, as described above, is in direct relationship to V_2, the transition intensity can be shifted at will by adjustment of V_1 and V_2.

If, finally, V_2 and V_1 are more or less in phase opposition and if the amplitude of the latter is such that the partial voltage E in itself does not suffice to excite the luminescent layer 5 to luminesce, a primary radiation image on the photo-conductive layer 8 results in a luminance image in the layer 5 which is a positive image of the primary radiation image, this positive image appearing, however, in contrast to the first-mentioned case, on a dark background. Thus the contrast of the positive image thus obtained is greater than in the first-mentioned case and this contrast is the greater, the larger is the amplitude of V_1.

From the foregoing it will be obvious that an image intensifying device capable of being matched to different conditions and desires can be obtained by means of a solid-state image intensifier of the kind shown in FIG. 1, comprising an apertured third electrode in contact with the photo-conductive layer and fed by different voltages V_1 and V_2, provision being made of means for an adjustable variation of the difference between these voltages.

FIG. 3 shows an advantageous embodiment of the device according to the invention, in which the construction of the supply apparatus 2, to which the solid-state image intensifier 1, indicated only by the electrodes 4, 9 and 11, is connected is illustrated by a block diagram. The supply apparatus 2 of the device shown in FIG. 3 comprises a variable alternating-voltage source 31, supplying the frequency- and amplitude-variable input voltage for a first amplifier 32 having an adjustable amplification. The output of the amplifier 32 is connected to a transformer 33, the secondary winding of which is connected to the electrodes 4 and 11 (first electrode and second electrode) of the solid-state image intensifier 1, between which it produces a voltage V_2. The voltage of the alternating-voltage source 31 is also fed to a second adjustable amplifier 35 via an adjustable phase-shift device 34, which may be formed in known manner by the series combination of a capacitor and a resistor, but which may be constructed in a different manner. The output of the amplifier 35 is connected to a transformer 36, the secondary winding of which is connected via a commutator 37 to the electrodes 4 and 9 (first electrode and third electrode) of the image intensifier 1, to which electrodes a voltage V_1 is fed. It will be obvious that owing to the controllability of the amplification obtained by the amplifiers 32 and 35 and owing to the controllability of the phase difference between the input voltages fed to the amplifiers 32 and 35 by means of the phase-shift device 34 the voltages V_2 and V_1 can be varied at will with respect to their amplitude and phase-difference. In order to obtain the simplest structure of the phase-shift device 34, the supply circuit of the electrodes 4 and 9 includes a commutator 37, which varies the phase difference between the voltages V_1 and V_2 by 180° by switching over. This commutator could also be included in the supply circuit of the electrodes 4 and 11.

It should be noted that in the foregoing explanation given with reference to FIG. 2 for the influence of V_2 and V_1 on the characteristic curve of the solid-state image intensifier 1, reference is mainly made to the in-phase and the opposite-phase condition of the voltages V_2 and

V_1, but that it should be considered that another phase difference between these voltages is possible and has its influence on the characteristic curve. The effect described above for voltages V_2 and V_1 of opposite phases occurs when the phase difference between these voltages exceeds 90°; the greater this phase difference, the greater is the effect. In the device shown in FIG. 3 this phase difference can be completely adjusted at will owing to the introduction of the phase-shift device **34** and the commutator **37**.

FIG. 4 shows in a diagram a further composition of the supply apparatus **2**. One terminal of a variable alternating-voltage source **41** is directly connected to the electrode **11** of the image intensifier **1**. The other terminal of the alternating-voltage source **41** is connected via a variable impedance **42** to the electrode **4** and via a second variable impedance **43** to the electrode **9** of the image intensifier. The impedances **42** and **43** may be formed by adjustable resistors, inductors or capacitors or combinations thereof. The impedance **42** is furthermore shunted by a short-circuit switch **44** and the impedance **43** is shunted by a short-circuit switch **45**. When the two switches are open and when the impedances **42** and **43** provide a phase shift having a difference of not more than 90°, the voltages V_2 and V_1 fed to the electrodes of the intensifier may be considered to some extent as in-phase voltages, while their amplitude ratio can be controlled by the adjustment of the impedances **42** and **43**. When the switch **44** is closed, the impedance **43** produces an electric feedback, since with an increasing irradiation of the photo-conductive layer in the intensifier **1** the current passing from the electrode **11** to the electrode **9** and subsequently through the impedance **43** increases, resulting in an increase of the amplitude of V_1. When the alternating-voltage source **41** and the impedance **43** are adjusted so that the intensifier **1** produces a negative image, this means a feedback which attenuates the contrast in the reproduced image.

However, when the switch **44** is opened and the switch **45** closed, V_1 and V_2 have a more or less opposite sense, if at least the impedance **43** does not produce a phase-shift of more than 90°; thus the above-mentioned effects can be obtained. Also in this case an electric feedback occurs, i.e. owing to the presence of the impedance **42**. This feedback is, in this case, positive, which gives rise to an enhancement of the contrast.

The device according to the invention illustrated in FIG. 5 differs from that shown in FIG. 1 in that the electrode wires **9** are not all connected to each other, but alternately, so that two electric groups are formed. Between these two groups is connected a direct-voltage source **51**, which feeds an adjustable direct bias voltage to these groups. Each of the two groups is furthermore connected via a capacitor **52** and **53** respectively to the same output terminal of the supply apparatus **2**, which supplies a voltage V_1 relative to the terminal to which the electrode **4** (first electrode) of the image intensifier is connected. The capacitors **52** and **53** prevent a direct short-circuit of the direct voltage source **51** and also a short-circuit of this source via the supply apparatus **2** and the intensifier **1**. If the latter cannot convey direct current between the output terminals and between the electrodes respectively, one of the capacitors **52** or **53** may be omitted. The bias voltage fed by the direct voltage source **51** via the two groups of the electrodes **9** to the photo-conductive layer of the intensifier **1** serves for enhancing in known manner the sensitivity of the photo-conductive layer, which is higher for direct voltages than for alternating voltages. By adjusting the bias voltage supplied by the direct voltage source **51**, the sensitivity of the photo-conductive layer in the intensifier can be controlled. It will be obvious that the bias voltage of the two electric groups of the wires of the third electrode **9** may be obtained by a different arrangement of the direct voltage source **51**, for example by including the latter in only one of the connections of the supply apparatus **2** to the two groups of the electrode **9**. The direct voltage source may, as is known, be replaced by oppositely directed rectifiers in the two connections.

The invention is not restricted to the use of the embodiment of a solid-state image intensifier as described with reference to FIG. 1. It is, for example, not necessary to sandwich between the luminescent layer and the photo-conductive layer a layer which screens the latter completely from the light produced in the former. By using optical feedback between the luminescent layer and the photo-conductive layer, in which case known measures should be taken to restrict the optical feedback locally to photo-conductive elements and the luminescent elements controlled by said photo-conductive elements, an intensified contrast of the reproduced image can be obtained if this image is a positive image, whereas in the case of a reproduced image in the form of a negative image the optical feedback results in a reduction of contrast. If the solid-state image intensifier in the device according to the invention is fed so that the reproduced image is a positive image, the optical feedback may give rise to instability, which then becomes manifest at an intensity of the primary radiation image which depends upon the supply voltages V_1 and V_2. Thus a memory effect may be obtained, in which the reproduced image is stored in the form of bright and dark parts, i.e. without intermediate shadings. This stored image may be erased, for example by reducing the voltage V_1, so that the image intensifier arrives in the region of a negative image reproduction, the feedback becoming then negative and the image intensifier being capable of returning to its initial state.

The device according to the invention may furthermore be provided with a solid-state image intensifier operated by direct voltage. In this case the luminescent layer and the neutral impedance layer must have a sufficient amount of direct-current conductivity; the supply apparatus can then feed direct voltages V_2 and V_1 to the electrodes of the intensifier, these voltages being required to be adjustable in value and polarity.

What is claimed is:

1. Apparatus comprising a solid-state image intensifier; said intensifier including a first electrode, an electric-field-responsive luminescent layer over the first electrode, a radiation-responsive photoconductive layer over the luminescent layer, a layer of radiation-unresponsive impedance elements over the photoconductive layer, a second electrode over the impedance layer, and a grid-like third electrode extending between the luminescent layer and the impedance layer and contacting the photoconductive layer; means for maintaining a voltage difference V_2 between the first and second electrodes, means for maintaining a voltage difference V_1 between the first and third electrodes, V_1 and V_2 being different from zero and from each other, and means for varying the difference of V_1 and V_2 from each other.

2. Apparatus as set forth in claim **1** wherein V_1 and V_2 are direct-current voltages, and the varying means varies one of the magnitude and polarity of one of V_1 and V_2.

3. Apparatus as set forth in claim **2** wherein V_1 and V_2 have opposite polarities.

4. Apparatus as set forth in claim **3** wherein V_2 has a value at which, in the non-irradiated condition of the photoconductive layer, the luminescent layer luminesces due to V_2 alone, and V_1 has a value at which, in the irradiated condition of the photoconductive layer, the luminescent layer luminesces due to V_1 alone.

5. Apparatus as set forth in claim **1** wherein V_1 and V_2 are alternating-current voltages and the varying means varies one of the amplitude and phase of one of V_1 and V_2.

6. Apparatus as set forth in claim 5 wherein V_1 and V_2 have a phase difference of more than 90°.

7. Apparatus as set forth in claim 6 wherein V_2 has a value at which, in the non-irradiated condition of the photoconductive layer, the luminescent layer luminesces due to V_2 alone, and V_1 has a value at which, in the irradiated condition of the photoconductive layer, the luminescent layer luminesces due to V_1 alone.

8. Apparatus comprising a solid-state image intensifier; said intensifier including a first electrode, an electric-field-responsive luminescent layer over the first electrode, a radiation-responsive photoconductive layer over the luminescent layer, a layer of radiation-unresponsive impedance elements over the photo-conductive layer, a second electrode over the impedance layer, and a grid-like third electrode extending between the luminescent layer and the impedance layer and contacting the photoconductive layer; means for maintaining a voltage difference V_2 between the first and second electrodes, means for maintaining a voltage difference V_1 between the first and third electrodes, V_1 and V_2 being different from zero and from each other, and means for varying the difference of V_1 and V_2 from each other; said maintaining and varying means including a potential source connected to the second and third electrodes, and a variable impedance coupled between the third electrode and the first electrode.

9. Apparatus comprising a solid-state image intensifier; said intensifier including a first electrode, and electric-field-responsive luminescent layer over the first electrode, a radiation-responsive photoconductive layer over the luminescent layer, a layer of radiation-unresponsive

impedance elements over the photoconductive layer, a second electrode over the impedance layer, and a grid-like third electrode extending between the luminescent layer and the impedance layer and contacting the photoconductive layer; means for maintaining a voltage difference V_2 between the first and second electrodes, means for maintaining a voltage difference V_1 between the first and third electrodes, V_1 and V_2 being different from zero and from each other, and means for varying the difference of V_1 and V_2 from each other; said maintaining and varying means including a source of alternating-current voltage, a first amplifier coupled between said source and the first and second electrodes, a second amplifier connected between said source and the first and third electrodes, and an adjustable phase-shifting device connected to at least one of said amplifiers.

10. Apparatus as set forth in claim 9 including means for adjusting the amplitude of the voltage in the circuit of the phase-shifting device.

11. Apparatus as set forth in claim 9 wherein a reversing switch is provided for reversing the voltage applied to at least two of the electrodes.

References Cited by the Examiner

UNITED STATES PATENTS

2,916,630	12/59	Rosenberg	250—213
2,975,294	3/61	Kazan et al.	250—213
3,070,702	12/62	Marko	250—213

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