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[54] **ARRANGEMENTS INCLUDING IMAGE INTENSIFIER DEVICES**

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[52] **U.S. Cl.** .... **315/11,** 250/213 VT

[51] **Int. Cl.** **H01j 31/48**

[58] **Field of Search** .... 250/213 UT, 213 A, 250/213 R; 315/10, 11, 12

[56] **References Cited**

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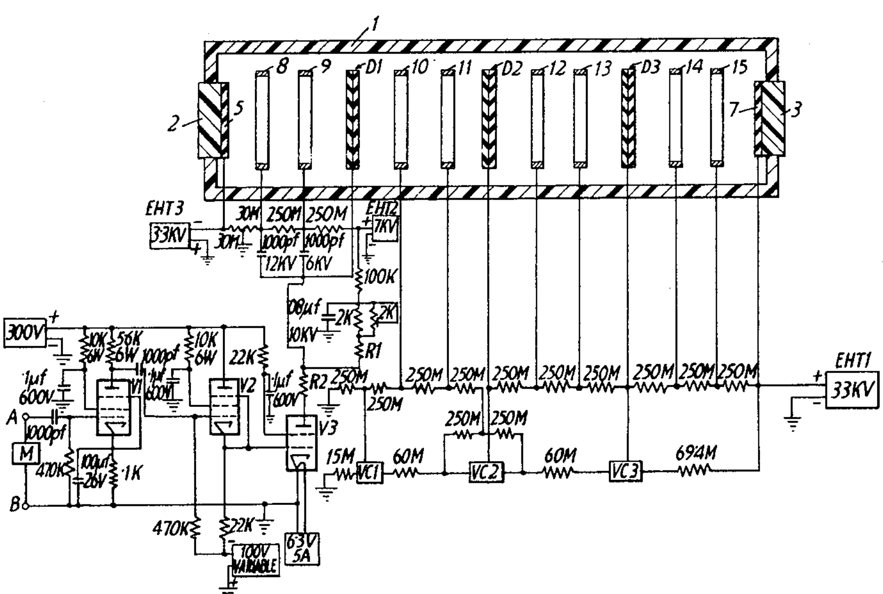
[57] **ABSTRACT**

An image intensifier arrangement is operated in a manner which allows observance of preselected events which occur during the occurrence of other events which may mask them. Normally the first stage of the intensifier is operative while the second stage is inoperative. When a preselected event occurs, an electrical pulse circuit switches off the first stage and switches on the second and subsequent stages. The pulse circuit is triggered by a monitoring device which monitors the input signals to the intensifier. The intensifier output may be photographed. In another embodiment, the electrons from the last stage, which may be the second stage, of the intensifier impinge on the target of a television camera tube. The target is scanned by an electron beam and the television signals produced thereby may be displayed and/or recorded for display at a later time.

7 Claims, 6 Drawing Figures



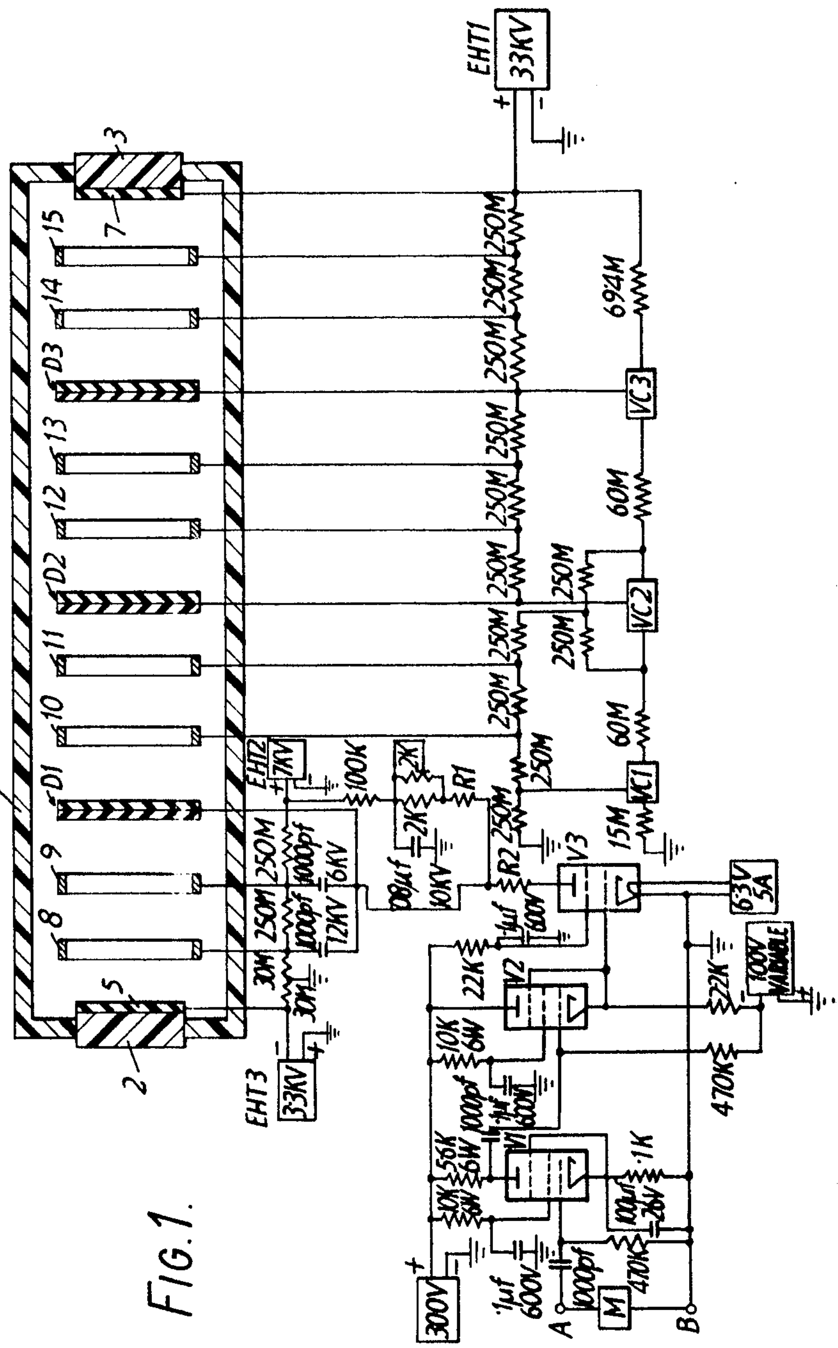


FIG. 1.

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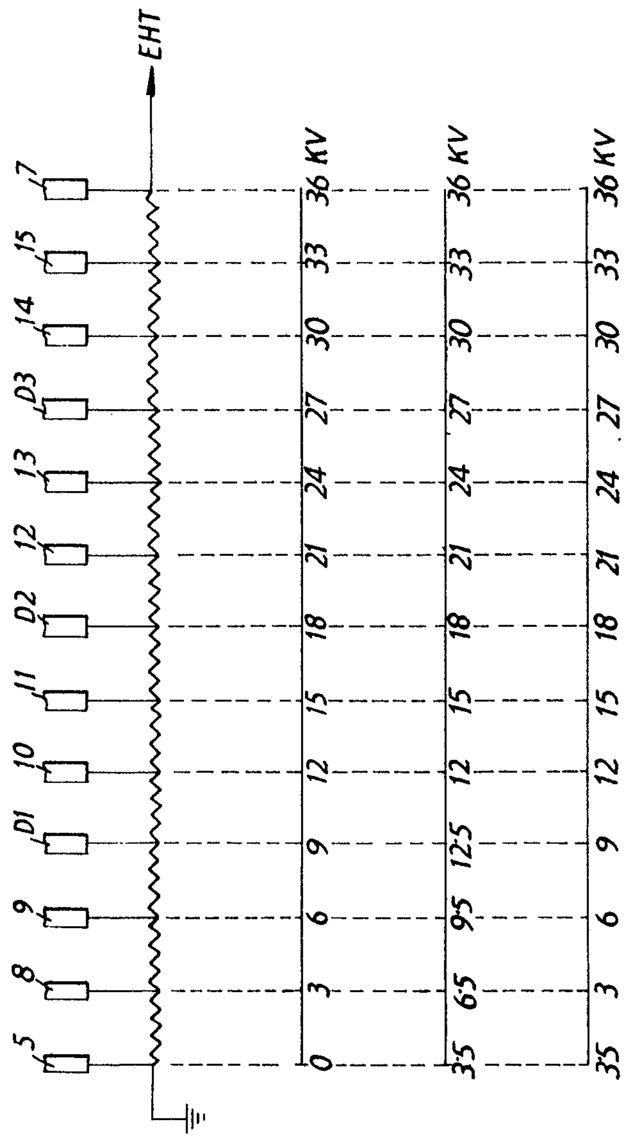

FIG. 2a. FIG. 2b. FIG. 2c. FIG. 2d.

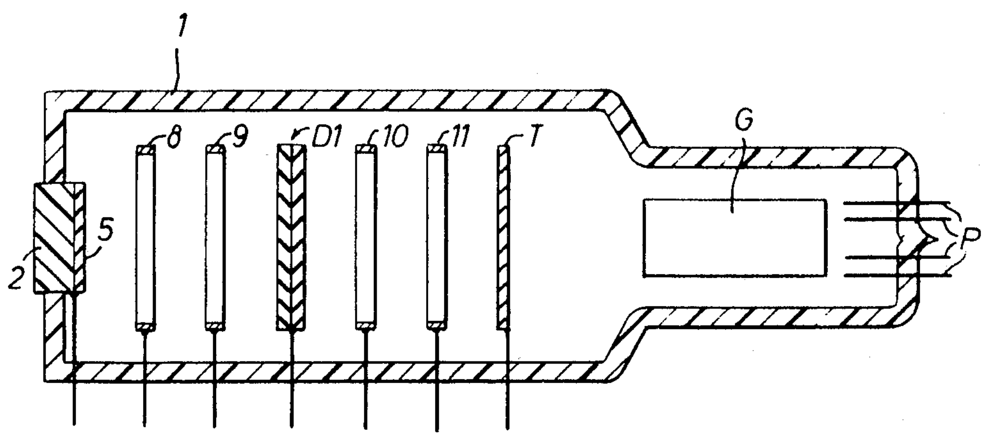

FIG. 3

ARRANGEMENTS INCLUDING IMAGE INTENSIFIER DEVICES

This invention relates to arrangements including image intensifier devices having more than one stage. The first stage includes a photo-cathode and a phosphor screen and, preferably, one or more focusing electrodes. The second stage includes a photo-cathode, and one or more focusing electrodes which cause the electrons from the photo-cathode to be focused to a new image plane. Such devices are herein referred to as devices of the kind described.

Such an arrangement is suitable for intensifying preselected events of short duration especially when they occur during the occurrence of events of longer duration, or for events of a preselected energy level especially when they occur during the occurrence of events having a wider band of energies, which may tend to mask the preselected events.

The electrons from the second stage may then be utilized in any suitable manner. For example they may be utilized in further stages of image intensification; or they can be used to react with various forms of electron sensitive targets, such as storage targets. This type of selection is desirable in, for example, gamma ray imaging wherein gamma rays are directed onto a scintillating crystal and then viewed by an image intensifier device. The rays incident on the intensifier device may consist of rays of different energy levels, only a small range of which corresponds to the image, the others resulting from scattering of the gamma rays or from other processes which are not related to the image of interest.

It is an object of the invention to provide an arrangement which allows intensification and display of selected events.

According to the invention there is provided an arrangement comprising an image intensifier device and an electric circuit, said device including an input photocathode, first focusing electrode means; an intensifying electrode, second focusing electrode means and a receiving electrode for receiving electrons from said intensifying electrode, said circuit including means for applying respective substantially constant potentials to said input photocathode, said second focusing electrode means and said receiving electrode and means for applying respective potentials to said first focusing electrode means and said intensifying electrode such as to allow input signals received on said input photocathode to be transmitted to said intensifying electrode while preventing signals from being transmitted from said intensifying electrode to said receiving electrode, said circuit also including monitoring means for monitoring the input signals to said input photocathode and, when a signal occurs having a desired characteristic, for causing a voltage pulse to be applied to each of said first focusing electrode means and said intensifying electrode whereby said signal having a desired characteristic is intensified and transmitted to said receiving electrode while further input signals are prevented from being transmitted from said input photocathode to said intensifying electrode, said intensifying electrode having sufficient storage to allow time for said monitoring means to detect an input signal having adesired characteristic and the subsequent application of said voltage pulses.

In order that the invention may be clearly understood and readily carried into effect it will now be described

by way of example with reference to the accompanying drawings in which:

FIG. 1 illustrates diagrammatically an arrangement according to one example of the invention,

FIGS. 2*a* to 2*d* exemplify the principle of the operation of the arrangement shown in FIG. 1, and

FIG. 3 illustrates diagrammatically an arrangement according to another example of the invention.

Referring to FIG. 1 which illustrates one example of the invention, a 4-stage image intensifier tube has an insulating envelope **1** and input and output windows **2** and **3** respectively. Input window **2** supports a photo-cathode layer **5** while output window **3** supports a phosphor layer **7**. Spaced along the tube are intensifying electrodes **D1** to **D3** and ring focusing electrodes **8** to **15**. The electrodes D1 to D3 are of the known sandwich construction having a phosphor layer facing the input end of the tube and a photo-cathode layer facing the output end of the tube. The phosphor layer of electrode **D1** exhibits lag, that is it has a storage effect, the decay characteristic being chosen dependent upon the frequency of the events it is required to select. The material may be for example titanium-activated zinc silicate which has a decay period, and hence a storage period, of 5μ sec.

The principle of operation will now be described with reference to FIGS. 2*a* to 2*d*. FIG. 2*a* shows how the potentials may be applied to the electrodes of the tube by means of a divider chain connected between an EHT supply and earth while FIG. 2*b* illustrates the valves in KV which these potentials may have. With these potentials applied to the electrodes, all four stages would be operative, that is to say an image received on input photo-cathode **5** would be transmitted down the tube, intensified by electrodes D1 to D3 and displayed on output phosphor **7**. FIG. 2*c* indicates the potentials in KV applied to the electrodes for the tube to operate in a "receive only" mode, that is with the first stage operative and subsequent stages unresponsive to the output of the first stage (hereinafter referred to as the first state of the tube). It will be seen that the potential on electrode D1 exceeds by 500V the potential on electrode **10**, which is the first electrode in the second stage, so that the second stage is inoperative and the image received by the phosphor of electrode D1 is stored but not transmitted, the storage period depending upon the material of this phosphor. The potential on electrode D1 has thus been raised, and in order that the first stage shall remain operative and in a focused state the potentials on photo-cathode **5** and electrodes **8** and **9** are also raised by the same amount as electrode **D1**, in this case 3.5KV. FIG. 2*d* illustrates the potentials applied to the electrodes of the tube for the "transmission" mode, that is with the first stage inoperative and the remaining stages simultaneously operative (hereinafter referred to as the second state of the tube). It will be seen that the potential applied to electrode D1 has been reduced by 3.5KV to its previous value of 9KV so that the second and subsequent stages now transmit and intensify the image stored on the phosphor of electrode **D1**. The potential on electrode **8** has also been reduced by 3.5KV so that the potential thereon is now 500V below the potential on the input photo-cathode **5** and thus the first stage is inoperative during this transmission period. Further, the potential on electrode **9** has also been reduced by 3.5KV as it is found that transient changes in potential between electrodes **8, 9** and D1 can cause severe spurious signals to occur in the first stage which would normally break through and be intensified with the stored image, thus possibly resulting in serious noise conditions in the output image. By allowing electrodes **8**, **9** and D1 to maintain their relative potential differences, this cause of spurious signals is eliminated.

It will be seen from the preceding paragraph on the principle of operation that the potentials on only three electrodes requires to be varied, namely electrodes **8**, **9** and D1, as shown in FIGS. *2c* and *2d*. In practice, these changes of potential are obtained by pulsing techniques.

Referring again to FIG. 1, the potentials for photocathode **5** and electrodes **8**, **9** and D1 are obtained independently of the potentials for the remaining electrodes. To ease circuit problems in pulsing the tube, the potential on electrode **8** is in the region of the earth point and the photo-cathode **5** is run at −3.3KV from voltage source EHT3. The potentials for electrodes **8**, **9** and D1 are obtained from a 7KV voltage source EHT2 and associated resistor chain, and the potentials for the remaining electrodes are obtained from a 33KV voltage source EHT1 and a divider chain. The polarities of the three EHT sources are as indicated by the + and − signs on the leads adjacent thereto. The divider chain associated with voltage source EHT1 comprises a plurality of resistors together with three voltage controllers VC1, VC2 and VC3 which are manually adjustable in the manner of a fine tuner to provide a voltage variation of about 3 percent. So that the cut-off conditions in the second stage may be independent of the focusing potential applied to electrode D2, the potentials for the second stage electrodes **10** and **11** are obtained from the centre tap of a 500MΩ resistor chain connected across VC2.

The circuit described thusfar operates the tube in its first state, as hereinbefore defined. In this mode, the image on input photo-cathode **5** is transmitted to the phosphor layer of electrode D1 where it is stored. As mentioned previously, this storage period depends upon the material of the phosphor layer, and in the case of titanium-activated zinc silicate it is about 5μ sec. The storage period of the phosphor layer of electrode D1 is largely responsible for the repetition rate which can be employed, that is the frequency of the events which can be individually intensified and displayed, and in the case of titanium-activated zinc silicate the maximum useful repetition rate is about 10^5 per sec. If higher rates are required, then phosphors having a shorter decay time can be used, for example P16 or P24 phosphors according to the JEDEC classification.

As previously mentioned, the necessary changes in the potentials applied to the electrodes are achieved by means of pulses. The pulsing circuit operates in known manner and includes input terminals A and B to which triggering signals are applied from a monitoring device M which may be a photo-electric device, for example a photomultiplier tube, upon the occurrence of an event of interest. However, triggering signals may be obtained from any suitable means which operate sufficiently fast to allow the tube to be pulsed from its first state to its second state before the image on the phosphor of electrode D1 has decayed. The monitoring device may be arranged to produce a triggering pulse by, for example, pulse height analysis of the output of the photomultiplier or other means, a triggering pulse being produced only when the pulse height exceeds a preselected threshold. On the other hand if the times of the events are known then a pulse generator operating at appropriate times may be employed. The pulsing circuit comprises essentially a pentode V1 in a common cathode stage which drives a cathode follower V2 which is directly coupled to the control grid of a pulse tetrode V3. The common cathode stage provides theoretical voltage gain of approximately 60 but is overdriven (in order to square off the waveform) by the triggering signal which is 10V negative. This provides a 180V positive signal to feed the cathode follower which is used as a low impedance driver for the pulse tetrode V3, producing a pulse of 120V amplitude having a rise time of 0.25μ sec and a fall time of 1.5μ sec. The control grid of pulse tetrode V3 is held at −100V via a 2.2KΩ resistor and is switched well into conduction when the 120V pulse drives it into grid current. The tetrode is operated in the grid current region to ensure that it conducts as heavily as possible so as to reduce the rise time and ensure that the anode saturation voltage is kept low so as not to introduce a possible variable. When the tetrode is switched on, the 0.08μf reservoir capacitor discharges through the tetrode to produce a large negative voltage pulse which is applied to electrodes **8**, **9** and D1. The amplitude of this pulse is determined by the ratio R1/(R1+R2) with an additional 2KΩ resistor and a 2KΩ potentiometer included to allow a small variation. R1 and R2 are about 5KΩ and 4KΩ respectively, the precise value of the ratio being chosen so that the potentials on electrodes **8**, **9** and D1 are pulled down sufficiently for the tube to be switched from the first state to the second state (as hereinbefore defined). After transmitting the image stored on the phosphor layer of electrode D1, the tube returns to its first state to await the occurrence of the next event of interest.

If desired, the displayed images may be photographed.

The maximum framing rate when all the phosphors are silver-activated zinc sulphide is about 500 to 1,000 per sec. The framing rate can be increased by using phosphors having a shorter decay time. For example, employing titanium-activated zinc silicate for all the phosphors allows a maximum framing rate of 30,000 per sec. In this case however, the maximum tube gain will be between 10^4 and 4×10^4, as compared with about 10^6, due to the lower efficiency of zinc silicate as compared with zinc sulphide. Where photography is used to record the output of the tube, long exposure times can be used to capture a random event, as the signal displayed on phosphor **7** while the tube is in the first state will be only that due to the dark currents of the photocathodes of electrodes D2 and D3. This is unlikely to raise the fog level of even fast films for exposures of many minutes, as very low dark current bialkali photocathodes (antimony-sodium-potassium) may be used in these stages of the tube.

It may be desirable in certain applications to incorporate an additional circuit to limit the pulse repetition frequency, thereby protecting the pulsing circuit from excessive power dissipation. This additional circuit may suitably include a limiter comprising a triode connected across the grid leak of pentode V2 driven by a monostable which is fed from a diode pump staircase counter with sufficient leakage just to hold off at the required pulse repetition frequency, say 500 per sec.

The monostable could be designed to have an OFF recovery time of 0.1 sec so as not to cause undue loss of picture information whilst still affording a certain degree of protection to the pulsing circuit.

Referring now to FIG. 3, in which similar reference numerals denote similar parts to those shown in FIG. 1, an envelope 1 has an input window 2 which carries a photo-cathode 5. Focusing electrodes 8 and 9 focus electrons from photo-cathode 5 onto an intensifying electrode D1 of the known sandwich type having a phosphor layer on the side facing the input window 2 and a photo-cathode layer on the side remote therefrom. Electrons from the photo-cathode layer of electrode D1 are focused by focusing electrodes 10 and 11 onto a target T of a television camera tube system. The camera tube system has an electron gun structure G, and pins P for making electrical connections thereto are hermetically sealed through the envelope 1. In the form shown, the camera tube is of the all electrostatic type but it will be appreciated that magnetic focusing and/or deflection may be employed if desired. The target T may be of any suitable electron sensitive type. For example, it may comprise a material which exhibits electron bombardment induced conductivity or may comprise a two dimensional array of semiconductor diodes. In operation, the first stage of the intensifier is normally operative and the second stage is inoperative. When an event of interest having a desired characteristic occurs, the first stage of the intensifier is switched to be inoperative and the second stage is switched to be operative. The electrons from the photo-cathode layer of electrode D1 are focused onto the target T which is then scanned by electrons from the electron gun G. The television signals thereby produced may be displayed and/or recorded for display at a later time. In a further arrangement, a camera tube may be associated in like manner with an image intensifier having three or more stages. In this case, the second and subsequent stages of the intensifier may be switched to be simultaneously operative when a preselected event occurs. The potentials for the electrodes of the image intensifier may be derived and switched by means similar to those described with reference to FIG. 1.

An arrangement according to the invention thus allows preselected events having a desired characteristic to be observed, and a variety of terminal devices may be employed depending upon the use to be made of the information concerning these events.

Various modifications will be apparent to anyone skilled in the art. For example, the sandwich type intensifying electrodes D2 and/or D3 may be replaced by

other intensifying types of electrodes such as transmissive secondary electron emissive types. Also, the target T may be made of a material exhibiting secondary electron emission.

What I claim is:

1. An arrangement comprising an image intensifier device and an electric circuit, said device including an input photocathode, first focusing electrode means, an intensifying electrode, second focusing electrode means and a receiving electrode for receiving electrons from said intensifying electrode, said circuit including means for applying respective substantially constant potentials to said input photocathode, said second focusing electrode means and said receiving electrode and means for applying respective potentials to said first focusing electrode means and said intensifying electrode such as to allow input signals received on said input photocathode to be transmitted to said intensifying electrode while preventing signals from being transmitted from said intensifying electrode to said receiving electrode, said circuit also including monitoring means for monitoring the input signals to said input photocathode and, when a signal occurs having a desired characteristic, for causing a voltage pulse to be applied to each of said first focusing electrode means and said intensifying electrode whereby said signal having a desired characteristic is intensified and transmitted to said receiving electrode while further input signals are prevented from being transmitted from said input photocathode to said intensifying electrode, said intensifying electrode having sufficient storage to allow time for said monitoring means to detect an input signal having a desired characteristic and the subsequent application of said voltage pulses.

2. An arrangement according to claim 1 in which said receiving electrode comprises the target of a television camera tube.

3. An arrangement according to claim 1 in which said receiving electrode comprises a further intensifying electrode.

4. An arrangement according to claim 1 wherein said monitoring means comprises a photo-electric device.

5. An arrangement according to claim 4 wherein said photo-electric device comprises a photomultiplier.

6. An arrangement according to claim 2 wherein said target comprises an array of semiconductor diodes.

7. An arrangement according to claim 2 wherein said target comprises a material which exhibits electrons bombardment induced conductivity.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,767,961 Dated October 23, 1973

Inventor(s) Robert Paul Randall

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the title page, insert

-- [30] Foreign Application Priority Data

Nov. 19, 1969 Great Britain ..... 56531/69 --

Signed and sealed this 18th day of June 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

UNITED STATES PATENT OFFICE
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