Jan. 5, 1943. R. H. GEORGE 2,307,209

ELECTRONIC DEVICE

Filed Dec. 21, 1939 2 Sheets-Sheet 1

Fig. 1

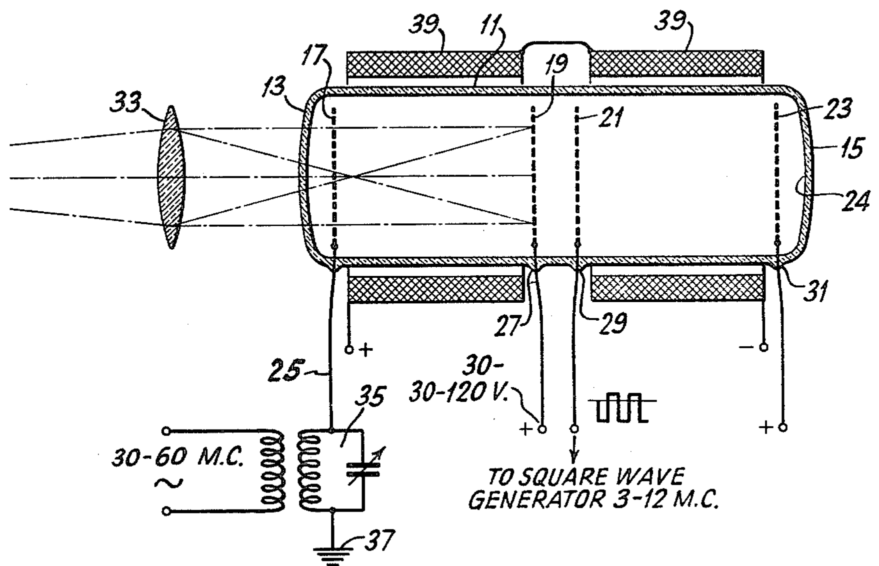
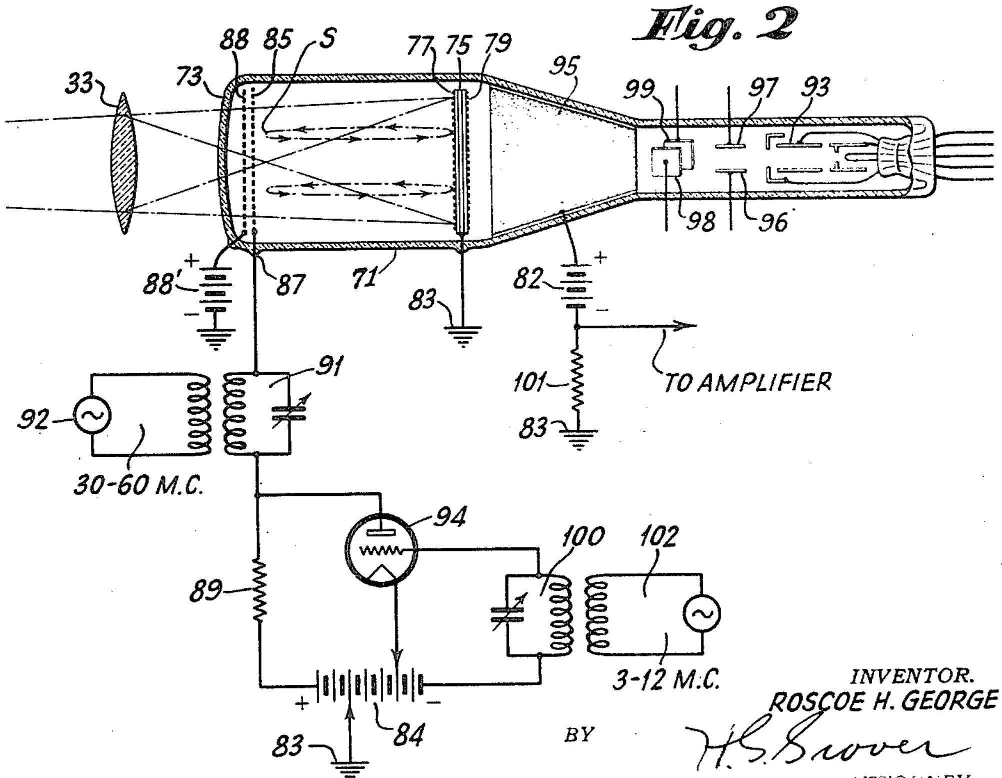


Fig. 2



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ELECTRONIC DEVICE

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Fig. 3

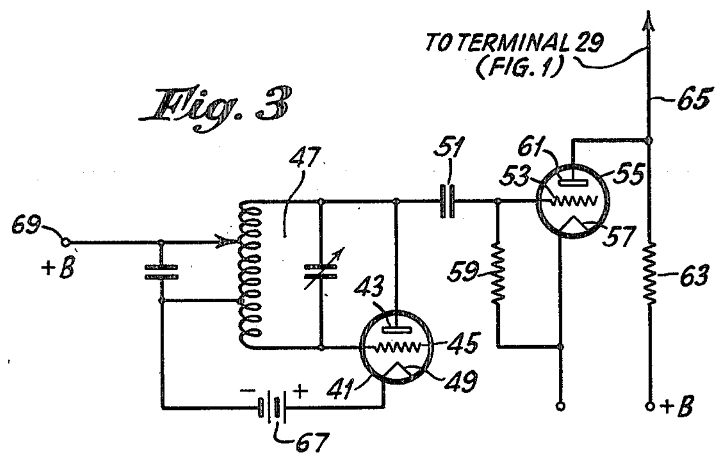


Fig. 4

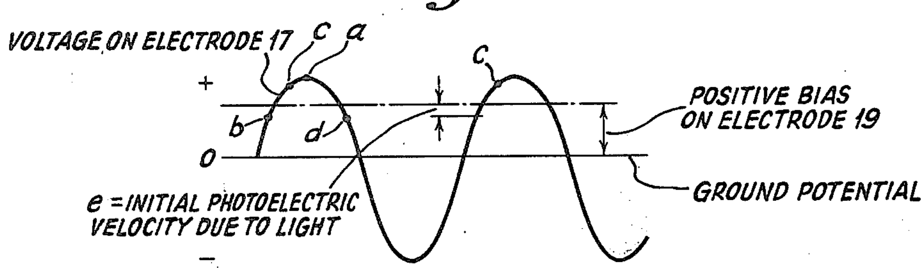
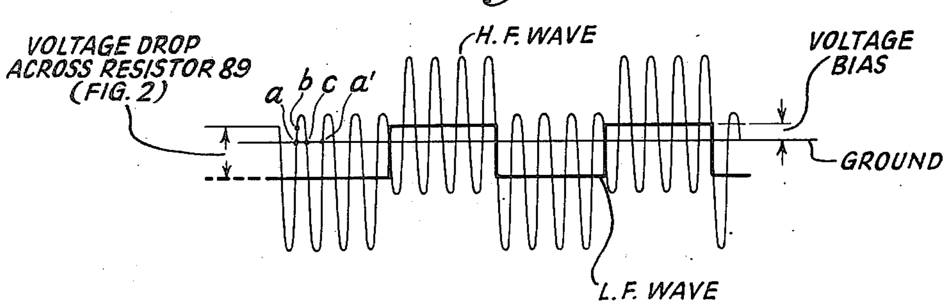


Fig. 5



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UNITED STATES PATENT OFFICE

2,307,209

ELECTRONIC DEVICE

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Application December 21, 1939, Serial No. 310,363

12 Claims. (Cl. 178—6.8)

This invention relates to electronic image or scanning tubes of the general types known as electronic amplifiers. More particularly the invention is concerned with a means and method of converting one form of energy into energy of another form or the invention is directed to the amplification or intensification of energy of the same or approximately the same character.

Further, the present invention is concerned with a method and means particularly applicable to amplifying light energy occurring either in the visible or invisible portions of the spectrum to produce in amplified form light energy in the visible portion of the spectrum.

In a slightly modified form the invention is directed to a method and means for converting one form of energy, such as light image (either visible or invisible) into an electronic image which is intensified or multiplied so as to produce an intensified representation of either an electric or an optical form which is characteristic of the original form of energy.

As the invention will herein be described it will be seen that one form thereof is particularly concerned with the provision of a light amplifying device adapted to make visible objects normally invisible or to provide for the conversion of radiant energy of one form into energy of another form. In general, the present invention provides an electronic device wherein through the utilization of secondary emission phenomena and the suitable control thereof, light energy of either a visible or invisible nature may be converted into light energy or a visible nature but greatly amplified in intensity or converted into an electrical replica greatly magnified from normal intensity which may be electronically translated into energy from which a visible replica can be produced.

In its preferred form the invention comprises an electronic tube wherein one or more photosensitive elements are provided and in which suitable control of the release of photoelectrons is provided and wherein there is provided, in turn, suitable means for controlling the release of secondary electrons which are electronic replicas of the initial spatially coordinated photoelectric emission but in magnified form, it being understood, of course, that accurate focusing of the initially released electrons is maintained. Through the use of suitably controlled generators or the like the released secondary electrons, produced from successive impacts of the released electrons upon a surface having a high secondary emission ratio, may be caused to initiate, on a suitable luminescent screen, visible light energy. Similarly, the electrons released by secondary emission may be caused to produce on a suitable mosaic electrode, arranged to be scanned electronically, an electrostatic replica of either the visible or invisible light image initially causing the release of primary photoelectrons. In the latter case, through scansion of the mosaic electrode by an electron beam or by a distributor of any suitable form there may be released to an external signaling circuit electrical energy representative of the activating radiant energy transformed into a wave train or series of signaling impulses.

To accomplish these results it will be appreciated that dynamic electronic multiplication (i. e. electron multiplication wherein the flow of primary and secondary electrons takes place along substantially the same path and in which the primary and secondary electrons flow in substantially the same, or in the case of some types of tubes in opposite directions) occurs within the tube so that an initially produced electronic image becomes substantially intensified prior to utilization for the ultimate production of an optical replica. In systems wherein dynamic electronic multiplication occurs the phenomena is usually associated with wave energy of alternating characteristic. In the present invention the time period of dynamic multiplication is preferably regulated by a controlling alternating current wave from which control potentials are applied at relatively rapid rates to regulate the periods of electron impact at predetermined areas within the tube whereat electron multiplication results because of secondary emission properties of the impacted areas.

Accordingly, among the objects of invention are included those of developing a secondary emission electronic image of any of the potential, current or charge types in a form which is substantially intensified as compared to that causing the primary emission electronic image; that of providing a suitable method and means for directly amplifying a light image; that of providing a suitable method and means for increasing the magnitude of electrostatic charges from which a wave train of signal energy representative of a light image are derived; and that of providing a simplified arrangement for converting energy of one form into energy of another form.

Still other objects and advantages of the invention will be found set forth in the description of the invention and also by the hereinafter appended claims when each is read in connection with the accompanying drawings wherein

Figure 1 illustrates one form of a light amplifier tube particularly adapted for converting radiant energy of either a visible or invisible form into magnified radiant energy of a visible nature;

Fig. 2 represents a modification of the arrangement of Fig. 1 particularly adapted for use as an image scanning tube as useful in television systems;

Figure 3 illustrates in a schematic manner one of a number of suitable electrical circuits for deriving operating energy for controlling the operation of the tubes of either Fig. 1 or Fig. 2.

Figure 4 represents diagrammatically the relationship between the accelerating alternating voltage and the biasing voltage applied to the photoelectrically active electrode element; and

Figure 5 represents in diagrammatic manner the relationship between the changes in control voltage between maximums and minimums and the frequency of the oscillator controlling the release of secondary electrons; and in this figure time is represented as the abscissa and the amplitude of the controlling generators as the ordinate values.

Referring now directly to Fig. 1 for a further understanding of the invention, there is provided an envelope 11 having a front viewing window 13 and a rear viewing window 15. The tube envelope 11 is suitably evacuated and contains therein the electrode elements 17, 19 and 21 which are each in the general form of gridlike elements and which are preferably formed from a conducting mesh, later to be explained. Immediately in front of the rear viewing window 15 is still an additional electron accelerating electrode element 23. This element 23 is in close proximity to the tube end wall 24 which is coated with a suitable luminescent material preferably having a relative short time lag. The short time lag screen prevents regeneration, as will later be apparent. Also, where desired, the electrode 23 may rest directly upon the luminescent target. It is desirable in some instances to support the luminescent screen upon a substantially transparent element positioned intermediate the tube end wall 24 and the electrode element 23 where it is desired to spray or deposit the screen externally of the tube blank and prior to assembly. By such construction it is easier to provide the luminescent material support element as a true planar structure even though the tube blank be slightly curved. Also, under some conditions where the time lag can be short, as will later be apparent, the element 23 may of itself constitute a conducting thermal type screen of either the metallic form or a carbonized woven or fabric screen of the general type already known and used in the art.

All of the electrode elements 17, 19, 21 and 23 are arranged to connect to external circuits by way of the conducting leads 25, 27, 29 and 31, respectively which may emerge from the tube wall through a common supporting press member held in a single evacuating stem. The electrode 19 is preferably formed as a conducting wire cloth of relatively fine mesh and is suitably photosensitived in a well known manner, e. g. by introduction of the photosensitive material in a vapor state with some suitably photoelectrically active element, such as caesium, potassium or any other element found in the same group and series of the periodic series of the elements. The electrodes 17 and 21 are also formed from conducting wires woven into a mesh but the mesh in the case of elements 17 and 21 is relatively coarse. The coarse mesh for the electrode 17, as will later be apparent, is for the purpose of preventing the absorption of any substantial amount of light which should reach the photosensitive mesh 19 and the coarseness of the mesh for the electrode 21 is for the purpose of preventing the absorption of electrons which are from time to time to pass therethrough after being drawn away from element 19. The light image which is to be amplified or converted from an invisible or visible form into an intensified visible form is directed by means of a suitable optical system 33 so as to impinge upon the photoelectrically activated meshlike conducting electrode 19.

To these electrodes there is preferably applied at the terminal point 27 a suitable positive voltage, varying for example between 30 and 120 volts positive relative to ground. To the electrode 17 there is supplied, by way of the tank circuit 35 (usually comprising parallelly connected inductance and capacity elements) connected at one end thereof to the conducting terminal 25 and at the other end thereof to ground at 37, suitable high frequency energy of relatively high amplitude as compared to the voltage applied to the terminal 27 of the light sensitive electrode 19.

The spacing between the electrodes 17 and 19 is somewhat critical, as will be appreciated from what is to follow. If it be assumed that the frequency of the energy supplied to the electrode element 17 by way of the conductor 25 from the tank circuit 35 is of a frequency varying between 30 and 60 megacycles it will be appreciated that the geometry of the tube, if electrons which are released under the influence of light on the photosensitive electrode 19 are not to reach the elements 17, the electrode spacing must be so related to the frequency of the energy applied to the electrode and the electron transit time between electrodes 19 and 17 that an electron released from the photoelectrically active surface 19 and subjected to an acceleration in the direction of the electrode 17 by virtue of a predetermined portion of the positive half of the cycle of the high frequency energy applied thereto will move through a distance just slightly less than the distance between the electrodes 19 and 17. As the polarity of the high frequency energy supplied to the electrode 17 by way of the tank circuit 35 changes in direction toward the negative half of its cycle, it is, of course, immediately apparent that the positive voltage relative to ground applied to the photoelectrically active element 19 becomes effective to draw electrons in the space between the electrodes 17 and 19 over to the electrode 19 and the electrons so drawn back then strike the electrode 19 to release secondary electrons for each primary electron arriving at the surface 19.

The number of secondary electrons released at each impact of electrons at the electrode 19 is, naturally, determined by the surface characteristic of the electrode 19. One important factor controlling the number of secondary electrons released per arriving primary electron is the value of the direct current bias applied to the electrode 19 at terminal 27 and also the amplitude of the controlling alternating current wave applied to the electrode 17 (this, of course, in addition to the surface characteristic of the electrode 19). This is because these two factors determine the impact velocity of the electrons upon the surface 19 and the magnitude of the bias on electrode 19 relative to the amplitude of the applied alternating current wave on electrode 17 determines the portion of the alternating current wave cycle at which it is possible to release secondary electrons from the surface 19. Since the frequency of the alternating current wave applied to the electrode 17 determines to a substantial extent the required spacing between electrodes 17 and 19 it will be appreciated that an increase in the alternating current frequency permits closer electrode spacing and increases in frequency, (for constant electrode spacing) permits greater amplitudes of the alternating current and also higher bias on electrode 19 (due to decreases in electron transit time because of the shorter period control cycle) so that higher impact velocities at electrode 19 may result. The impact velocity in each instance is due, of course, both to the motion of the electrons provided by the alternating current applied at electrode 17 and the acceleration provided by the positive bias on electrode 19.

By referring to Fig. 4 it will be seen that the high frequency voltage wave *a* at predetermined time periods overcomes the positive bias on the photosensitive element 19. Substantially no electrons leave the photosensitive surface 19 when the high frequency voltage wave is negative relative to points *b* or *d* because of the positive bias holding electrons to the surface 19. Nominally, electrons would not leave the surface 19 under light activation thereof except when the high frequency wave *a* was more positive than the bias voltage but with electrons released by light having some initial velocity (variable) with the color of the impinging light and determined in accordance with Planck's constant and the work function) this effect is caused to take place in regions conventionally represented as *b* and *d* for monochromatic light.

It is thought that the only released photoelectrons which are effective to release secondary electrons upon returning to the surface 19 under the control of the alternating current wave supplied to electrode 17 are those electrons which are released in the region schematically represented between points *b* and *c* because those electrons released between *c* and *d* return to the surface 19 when the polarity of electrode 17 changes negative under the control of the alternating current wave in such a manner that secondary electrons cannot be released because there is a lack of any accelerating voltage between elements 17 and 19 at such times. These secondary electrons then are added to the primary electrons released at the instant under light activation. With the energy continuously applied to the electrode 17 by way of the tank circuit 35, it is apparent that there will be an oscillation of both primary and secondary electrons back and forth in the space between electrodes 19 and 17 which takes place along substantially the same path so that those electrons which return to the surface 19 strike it each time at substantially the same point to prevent diffusion, since in any image device the circle of confusion is always of minimum diameter. However, with a positive voltage applied to the electrode 19 and the spacing between the electrodes 19 and 17 being of proper order (as above noted), it is readily apparent that released electrons just fail to reach the element 17 in the course of normal oscillation. After the electrons have oscillated through the predetermined number of oscillations, for example, after a predetermined number of cycles of oscillations supplied to the electrode 17 in the space between the electrodes 19 and 17 so as to release for each impact upon the electrode 19 secondary electrons, there is applied to the electrode element 21 by way of the terminal connection 29 a suitable square topped voltage wave whose frequency is preferably from 10% to 20% of that of the frequency of the energy supplied upon the electrode 17. The energy from the square top wave generator operates to cause the electrode member 21 to be carried positive at the frequency of the square wave energy source connected at terminal 29 for periods when the energy applied is positive in sign and of sufficient magnitude to overcome any applied bias. After a predetermined number of cycles of energy applied to the electrode 17, it can be seen that due to the geometry of the tube and the relatively close spacing between the electrode elements 19 and 21, whatever electrons are arriving at the electrode 19 at that period of time when the electrode member 21 is carried positive will pass directly through these two electrodes and become subjected to an accelerating field toward the window 15 due to the potential applied to terminal 31 and the target screen 23.

The target or screen element 23 is preferably maintained at positive potential relative to ground, and at a voltage varying between 500 and 5,000 volts, so that whenever the electrode element 21 becomes positive it causes the electrons in the space between the electrodes 19 and 17 to be drawn through it in order that they may impinge upon the target or screen 23. The electron flow impacting upon the target element at relatively light velocity causes the target area to luminesce and to appear with intensity proportional to the impacting electron density. In this way the electrode element 21 functions in a nature somewhat similar to the functioning of the control grid in the usual type of vacuum tube amplifier in that this electrode element 21 determines in accordance with whether its potential is positive or negative relative to ground (this latter being a function of polarity of the square energy applied), whether or not electrons pass through the space or area of the tube between the photosensitive electrode 19 and the target electrode 23.

In order that the electrons initially released from the photoelectric element 19 may be maintained in the proper spatial relationship with respect to the light image which causes their initial release, a suitable electron focusing coil 39 is provided. This coil is arranged to extend longitudinally for substantially the complete tube length. By virtue of the produced electromagnetic field of the coil 39 there is such a concentration of the electrons that the electrons are maintained, in motion under accelerating potentials, in such spatial relationship that the electron motion is along a path longitudinal of the tube 11. In this way the spatial position of the electrons within tube 11 will be exactly related to the spatial portion of the light points of the image in the tube window 13 which causes the initial release of the electrons. Of course, it is apparent that there may be substituted for the electro-magnetic focusing coil 39 a suitable form of electrostatic focusing field which readily can be produced by positioning metal bands within the tube and applying suitable potentials thereto or the focusing electrodes may be produced by applying, with suitable spacing, conducting coatings to the interior surface of the tube wall, and then applying to these coatings suitable potentials, all as is now well known in the art.

In accordance with the electron impact upon the target or screen electrode element 23, there is observable through the rear end 15 of the tube 11 an intensified or amplified replica of the light image which is directed by way of the optical system 33 upon the photosensitive cathode element 19. In cases where the photosensitive cathode 19 is photosensitized with materials highly sensitive in either an ultra-violet or infrared regions of the spectrum, the tube 19, of course, provides for the conversion of radiant energy normally invisible into visible radiations. In cases where visible light is focused upon the photosensitive cathode 19 the device operates to produce magnified light representations of that optical image initially impressed upon the photosensitive cathode.

The arrangement of the optical system shown at 33 herein, it is to be appreciated, is only a schematic showing of a complete optical system. It is usually preferable to focus an erect image of the object to be viewed upon the photosensitive cathode 19 so that an erect image is projected upon the screen or target electrode 23. This then precludes the necessity of providing an optical system for viewing the screen 23 although it is, of course, to be appreciated that where an optical system for inverting the image is used in connection with viewing, the image focussed upon the photo cathode 19 is preferably to be inverted. However, where electrostatic focusing systems are utilized it is possible to obtain cross-over of the image directly within the tube through the use of suitable potentials upon the several focusing electrodes. In this event it will be appreciated that in a case where the electrostatic focusing system provides for cross-over in that portion of the tube between the cathode element 19 and the target element 23 it is possible to project an inverted image upon the photosensitive cathode and still produce upon the target electrode 23 an erect image, it being assumed that there will be no inversion of the image in the area between the cathode electrode 19 and the accelerating electrode 17. Still further, it is frequently desirable to provide a combination of electromagnetic and electrostatic focusing means for the electrons flowing within the tube in which event the magnetic focusing would usually be provided for that portion of the tube between the electrodes 19 and 17 and the electrostatic focusing system would be utilized for that portion of the tube upon which the produced image becomes visible.

As was above explained in order to improve the operation there is applied to the controlling electrode 21, by way of the terminal connection 29, a voltage of substantially square-top wave form. The general form of this wave, in contrast to a substantially sine wave characteristic, of the voltage applied to the terminal 25 of the electrode 17, has been shown and sketched adjacent the terminal 29. It can be appreciated from what was above explained with the frequency of the square-top wave applied to the terminal 29 being about $^1/_{20}$ to $^1/_{10}$ that of the alternating current applied to the electrode 17, that during each cycle of the square wave the high frequency wave will pass through several complete cycles, varying in number between 5 and 10 in accordance with the chosen ratio above assumed. The voltage variations from a minimum to a maximum of the square wave, it will be appreciated from the designations on the wave form shown adjacent the terminal 29 and also from Fig. 5, causes the voltage applied to the photoelectrically responsive electrode 19 during the positive half cycles to be relatively negative with respect to the element 21 so that the element 21 functions, in effect, as a positive grid element between the photoelectric element 19 and the target or screen electrode 23 to permit electrons to flow through the tube envelope 11 in the space between the electrodes 19 and the target 23.

While many forms of suitable circuit arrangements may be provided for obtaining this square wave one suitable form is shown by Fig. 3 where the tube 41 is connected as an oscillator with the anode or plate electrode 43 and the grid or control electrode 45 connected to the end terminals of the usual tank circuit 47. The tube cathode element 49 is then connected at a central point in the tank circuit. This circuit, it can be seen, is a substantial duplicate of the well-known Hartley form of oscillator and requires no further explanation.

The amplitude of the oscillations developed by the oscillator tube 41 are relatively high. These oscillations then are directed by way of the coupling condenser 51 (although other forms of coupling might be used) to energize the control electrode 53 of an amplifier 55. Between the control electrode 53 and the cathode 57 of the amplifier the usual leak resistor 59 is provided. The tube 55 is of such characteristics that because of the substantial amplitude of the oscillations developed from the oscillator 41 the tube will saturate at predetermined time periods corresponding to a predetermined voltage output from the oscillator 41 and thus produce the square top wave form indicated on Fig. 5. Output energy from the amplifier 55 is fed from the plate or anode electrode 61 which is energized from a suitable source of positive voltage through a load resistor 63 so that output energy flows through conductor 65 which connects to terminal point 29 in Fig. 1. The values of inductance and capacity of the tank circuit 47 for the oscillator 41 are suitably chosen so that the natural period of oscillation of this tube corresponds to the assumed frequency varying between 3 and 12 megacycles, which was above assumed as being the frequency applied to the terminal point 29.

Suitable bias for the grid or control electrode 45 of the oscillator 41 is provided by way of the biasing source 67 and suitable anode potential for the oscillator tube 41 is provided by the source of voltage connected at terminal point 69 and poled positively relative thereto.

In a modification of the invention, shown by Fig. 2. which is particularly applicable to a transmitter type tube, an end window 73 through which an optical image is directed by means of a suitable optical system 33 similar, for example, to that shown by Fig. 1 is formed as a part of the tube envelope 71. The optical image is projected internally of the tube envelope 71 so as to impinge upon the portion of a double mosaic electrode 75 which faces toward the end window 73. The double mosaic electrode 75 has that surface 77 thereof which faces the end window 73 formed from material which is both photosensitive and capable of copiously emitting secondary electrons. The rear side 79 of the double mosaic electrode 73 is formed preferably from material in which a greatly reduced number of secondary electrons as per impinging primary are released. Such material, for example, may be various forms of carbonized surfaces and the like which, while conducting are poor secondary emitters. This type of electrode, it can be seen, will serve the purpose of enabling the element to acquire a negative charge from the scanning beam, as later will be explained. The general structure of the double mosaic electrode 75 may be substantially like that which has already been described in the art by patents granted to L. E. Flory and W. Hickok, Nos. 2,045,984 and 2,047,369, respectively. Such an electrode is formed from a conducting mesh of which the various wires of the mesh are insulated, such as by an enameled coating, to provide thereover a desired thickness of insulating coating. The interstices of the mesh are then packed in suitable manner, as already explained in the art, with conducting material such, for example, as a material which may be formed from an amalgam of silver. The conducting packings are pressed into the interstices of the mesh-like conductor, after it has been suitably enameled, so that the conducting material may have its end portion which faces toward the end viewing window 73 suitably photosensitized with caesium, potassium or other suitable photoelectric material, depending upon the response characteristic desired and depending upon whether or not the device is to be most highly sensitive to light from the visible or invisible portions of the spectrum. In this way high secondary emission is obtained from photosensitized surface 77 of the double mosaic electrode. The rear surface 79 of the conducting plug members of the double mosaic is preferably suitably carbonized, as above suggested, in order that reduced secondary emission may result.

The complete double mosaic electrode then has the conducting mesh connected to a suitable terminal point 81 which may be grounded at 83. This is done in order to maintain the mosaic at a definite reference potential.

Closely adjacent the end window 73 there is positioned an electrode 85 of relatively coarse mesh corresponding substantially to the electrode 17 of Fig. 1. This electrode connects to the terminal point 87 which connects to the tuned circuit 91 and thence through resistor 89 to ground 83 through a portion of battery or other voltage source 84, as will hereinafter be more fully described.

At the opposite end of the tube 71 there is provided a suitable means for developing a cathode ray beam which is to scan the rear surface 79 of the conducting elements of the double mosaic which have relatively low secondary emission. In order to develop this electron beam there is provided an electron emitter, a suitable control electrode and an accelerating and focusing anode, all of which elements are conventionally represented and are well known in the art. On the inner surface of the conical portion tube there is provided usually a conducting coating 95 which is to serve as a second anode of the tube and which is maintained at a relatively high potential with respect to the first anode of the electron gun 93 and also at a further higher potential relative to the emitting cathode.

In order to deflect the cathode ray beam developed from the gun 93 and to cause it to traverse the mosaic electrode 75 along bi-directional paths suitable deflecting means, such as the conventionally represented electrostatic deflecting plates 96, 97, and 98 and 99 are provided, although it is obvious that electromagnetic deflection may be substituted in whole or in part.

With the rear surface 79 of the conducting elements of the double mosaic 75 having been suitably treated so as to produce relatively low secondary emission, it will be appreciated that the electrons from the scanning beam developed from the electron gun 93 may cause the conducting elements to acquire a charge so as to be at a potential varying, for example, between ground potential and a limiting value somewhat negative with respect to ground. The limiting value may be considered as being dependent upon a number of quantities, such as the beam velocity, the location of the bias element 82, the secondary emission from the surface 79 and the general geometry of the tube. Under these conditions, it will be understood, that the beam current of the cathode ray beam in excess of the amount necessary to charge the elements 79 is returned to the conducting coating 95 by virtue of the negative potential created upon the mosaic electrode, which potential develops because of impact of the scanning beam.

In this arrangement the battery or bias unit 82, which is an element preferably having low distributed capacity to ground, is usually connected intermediate the second anode 95 and the output resistor 101 which connects to ground. With this connection the bias unit is poled with its positive terminal connecting to the anode 95. It is possible, however, under some conditions of operation, to connect the bias unit 82 between the mesh 75 of the double mosaic and ground at 83. This form of connection, however, usually requires the bias source to be poled so that the positive terminal will then be connected to ground which will maintain the mesh 75 negative relative to the anode 95.

Any current which flows between the mosaic surface 79 and ground 83 must flow through the resistor 101 and provide the signal current which is to be fed to the amplifier (not shown but indicated).

In order to multiply the photoelectric current released from the photosensitized ends 77 of the conducting pin members forming the double mosaic 75 a high frequency voltage of a value varying between 30 and 60 megacycles, for example, is supplied from the source 92 and the tuned circuit 91, so as to be applied to the electrode 85 by way of the terminal connection 87 and to be superimposed upon a pulsating direct current voltage which appears across the resistor 89. The tube 94 which has its output circuit so arranged as to include the resistor 89 has provided as part of its input circuit the tuned circuit 100 comprising inductive and capacitive elements tuned to the frequency of the source 102, conventionally represented. The coarse mesh electrode 85 has preferably also been treated so as to prevent secondary emission therefrom.

Whenever the tube 94 is passing a maximum current the voltage drop occurring across the resistor 89 is considerably greater than that of the bias voltage applied to the electrode 85 from that portion of the source 84 which is connected between the electrode 85 and ground 83.

As was above explained, in connection with Fig. 1, whenever the various portions and the frequency of the oscillator 92 are properly adjusted the photoelectrons which are released from the photoelectric coating 77 on the conducting pins of the double mosaic electrode 75 are released during the interval from a to b as shown particularly in connection with Fig. 5. It will be appreciated that the electrons will be drawn or driven toward the electrode element 85 until the point c in the cycle of the high frequency wave is reached, after which the opposing voltage causes the electrons to be decelerated until their motion is substantially arrested at a point conventionally represented on Fig. 2 as s, after which the combined electrical fields acting within the tube cause the electrons to be driven back along the path conventionally indicated by Fig. 2 until they impinge upon the photoelectric surface 77 with sufficient energy to cause the release of secondary electrons.

If the geometry and the parameters of the system have been properly adjusted the initial electrons will arrive back at the mosaic electrode 75 at point a' on the high frequency wave as indicated by Fig. 5, and the cycle will be repeated. After the secondary emission current has been built up over a number of cycles of the high frequency wave, as indicated by Fig. 5, the electrons must be drawn off to the electrode element 85 before the image is destroyed by space charge effects and also to allow for any changes in the optical image. In order to do this the current flowing through the resistor 89, which is to furnish bias on element 85, should be reduced to zero or substantially thereabouts periodically by means of the lower frequency voltage from the oscillator 102 driving the control electrode of the tube 94 to cut-off. This allows the voltage from the power supply or the source 84 to cause the electrons to reach the electrode element 85.

In a case where, due to the coarseness of the mesh of the electrode element 85, electrons tend to pass through the mesh toward the end wall 73 of the tube 71, such electrons may be collected by providing intermediate the electrode 85 and the end wall 73 of the tube still an additional electrode 88 to which a positive potential is continuously applied from a source 88'. However, it will be seen and appreciated that the greater the number of electrodes in the direct path of the optical image the greater will be the light loss and the greater the distortion. Therefore, it is usually desirable to make the mesh 88 slightly coarser than element 85 but where possible the inclusion of the additional electrode 88 should be avoided. In this connection, however, it can be seen that the auxiliary electrode 88 is so far out of focus that its presence is of relatively minor effect on the optical image cast upon the surface 77. Of course, it will be seen that in a short tube where element 85 is near the end wall 73 the inclusion of element 88 will tend to increase the capacity and thus perhaps waste power but where space requirements permit this capacity may be reduced by lengthening the tube and permitting element 88 near the face 73.

From what has been herein explained, therefore, it can be seen in connection with the modification of Fig. 2 that a suitable high frequency is applied to the electrode member 85 by way of the suitable source of alternating current 92 which is preferably of the order of 30 to 60 megacycles. Further, it can be seen, that due to the spacing of the double mosaic electrode 75 and the electrode element 85 all of the electrons released by light falling upon the photosensitized ends 77 of the conducting plugs of the double mosaic will be caused to be oscillated in the space between these electrodes in substantially the same manner as was described in connection with the oscillation of electrons between the elements 19 and 17 of Fig. 1. These electrons in their oscillations do not ordinarily reach the electrode 85 unless that electrode acquires a positive potential due to the source 84 as happens at certain intervals in the operation cycle, as above explained. For each time period while the electrons are oscillating in the space between the double mosaic 75 and the electrode 85, there are released for each impact of the electrons upon the photosensitized surface 77 of the double mosaic additional electrons in the form of secondary electrons. Whenever the electrons are released finally and subjected to a positive potential of relatively long period on the electrode 85 the electrons are accumulated by electrode elements 85 or 88 and passed to ground. The signals which are developed within the system and which signals are to control the amplifier connected to the upper end of the resistor 101 are such signals as result from the electrons reaching the conducting coating 95. It can be seen, therefore, that the signal current from this coating 95 is of such a direction that an increase in light on the photosensitive surface 77 tends to cause a decrease in the signal current. In cases where it is desired that an increase in light shall produce an increase in the signal current this effect may be obtained by an additional amplifier stage. In addition, it will be appreciated that one of the primary advantages of the image scanning system described in connection with the arrangement of Fig. 2 is that the output energy includes essentially the direct current component which is not realized in the case of many of the presently known forms of electronic light translating systems.

Having described my invention, what I claim is:

1. The method of intensifying the effect of an optical image which comprises photoelectronically converting an optical image into an electronic replica, developing an alternating current field to oscillate the produced electronic replica between predetermined planes for a selected time period and to produce at the end of the selected period an intensified electronic replica, arresting the oscillation of the electrons, collecting the entire oscillated and intensified electronic image at a plane spaced from one of the first-named planes immediately subsequent to the period of arrest, and cyclically shifting the control to cause the electron flow to be sequentially oscillated and arrested and collected.

2. The method of intensifying the effect of an optical image comprising photoelectronically converting an optical image into an electronic replica, developing an alternating current field to oscillate to produce electronic images between predetermined planes for a predetermined time period, momentarily arresting the oscillations, and then collecting the oscillated electronic images during the period of arrested oscillation at a utilization plane spaced from and parallel to one of the first-named planes to produce thereat an intensified representation of the entire original electronic image.

3. The method of intensifying the effect of an optical image directed upon an electronic tube having a photo-sensitive and secondary electron

emissive electrode element to receive the light image which comprises the steps of directing the optical image upon the light sensitive electrode element for photoelectronically producing an electronic replica of the optical image, applying a high frequency alternating electrostatic field to the developed electronic image to cause the electronic replica to oscillate between predetermined planes to produce dynamically electron multiplication of the developed electronic image at the electrode element only, subjecting the dynamically multiplied electronic image to a second electric field pulsating at a rate substantially less than that of the first alternating field to arrest dynamic multiplication and to simultaneously release the dynamically multiplied electronic image, and directing the released dynamically multiplied electronic image, at each period of release of the dynamically multiplied image, to an image utilization plane spaced from the first named planes.

4. A device for intensifying the effects of an optical image comprising photoelectric means for converting an optical image into an electronic replica, electrode means spacially positioned to receive the electronic replica, means for applying operating potentials between the photoelectric means and the said electrode means to oscillate the electronic replica between the said electrode means and a plane spaced a predetermined distance therefrom and to produce electron multiplication by dynamic action of the electronic replica impacting the said electrode means, means for controlling the application of the operating potentials to cause the electron multiplication to continue for a predetermined time interval and thereby to produce an intensified representation of the initially developed electronic replica, and means to control the applied potentials following predetermined time periods to interrupt the said electron multiplication, and means to collect the intensified electronic image.

5. An intensifying device for the conversion of optical images comprising secondary electron emissive photoelectric means for converting an optical image into an electronic replica, a plurality of parallel spaced electrodes including said first named means, means for developing an alternating current field between said electrodes to oscillate the produced electronic replica between said electrodes for a period of time to produce secondary electrons at said first means only, and means for collecting the oscillated electronic images in a plane parallel to and spaced from one of said electrodes to concurrently produce thereat an intensified representation of the entire original electronic image.

6. An electronic device for intensifying the effect of an optical image comprising a secondary electron emissive photosensitive electrode element to receive the light image and to produce an electronic replica of the optical image, a second electrode positioned parallel to and spaced from said first electrode, means for applying a high frequency alternating electrostatic field between the photosensitive and second electrodes to cause dynamically electron multiplication of the developed electronic image at the first electrode element only, a target electrode positioned outside the applied high frequency field, means positioned between the target electrode and said first electrode for subjecting the dynamically electron multiplied electronic image to a second alternating electrostatic field pulsating at a rate substantially less than that of the first alternating field to release the dynamically electron multiplied image, and means for directing and focusing the entire released dynamically electron multiplied electronic image upon the target electrode at each period of release of the dynamically multiplied image.

7. A device for intensifying the effect of an optical image which comprises secondary electron emissive means for photoelectronically converting an optical image into an electronic current replica, means including said first means for concurrently and dynamically electron multiplying the entire electronic current image for a predetermined time interval, means for focusing the original electronic image and to dynamically electron multiply the electronic current image during the period of image multiplication, means for developing at predetermined time intervals an electronic field to release the entire dynamically electron multiplied image, and means to simultaneously focus and direct the entire released image on to a utilization electrode.

8. An electronic device for intensifying the effect of an optical image comprising a light sensitive electrode capable of emitting secondary electrons, means for projecting and focusing an optical light image upon the electrode to produce an electronic current image replica of the optical image by the emission of photoelectrons, a grid electrode positioned parallel to and spaced from the light sensitive electrode, means for applying a first alternating electrostatic field of high frequency between the light sensitive electrode and the grid electrode to cause the emitted photoelectrons to repeatedly bombard only the light sensitive electrode for a predetermined length of time to produce secondary electrons and dynamic multiplication of the developed electron current image, means for subjecting the dynamic multiplied electronic image to a second alternating electrostatic field having a frequency substantially less than that of said first electrostatic field to arrest dynamic multiplication of the electronic image after the predetermined length of time and to simultaneously utilize the dynamically multiplied electronic image.

9. An electronic device for intensifying the effect of an optical image comprising a light responsive electrode capable of emitting secondary electrons, means for projecting and focusing an optical light image upon the electrode to produce an electronic image replica of the optical image by the emission of photoelectrons, a grid electrode spaced from and positioned parallel to the light responsive electrode, means for applying an alternating electrostatic field of high frequency between the light responsive electrode and the grid electrode, the intensity and frequency of the electrostatic field being such as to cause the emitted photoelectrons to repeatedly bombard the light responsive electrode for a predetermined number of times to produce secondary electrons and dynamic multiplication of the developed electron image at the light responsive electrode only and to prevent the electrons from reaching the grid electrode, means for subjecting the dynamic multiplied electronic image to a second electrostatic field pulsating at a rate substantially less than that of said first electrostatic field to arrest dynamic multiplication of the electronic image after the predetermined number of bombardments, and means for collecting the dynamically multiplied electronic image simultaneous with the arrest of dynamic multiplication.

10. An electronic device for intensifying the

effect of an optical image comprising a photo-sensitive electrode capable of emitting secondary electrons, means for projecting and focusing an optical light image upon the electrode to produce an electronic current image replica of the optical image by the emission of photoelectrons, a first grid electrode spaced from and positioned parallel to the photo-sensitive electrode, means for applying an alternating electrostatic field of high frequency between the photo-sensitive electrode and the grid electrode, the intensity and frequency of the electrostatic field being such as to cause the emitted photoelectrons to repeatedly bombard the photo-sensitive electrode only for a predetermined number of times to produce secondary electrons and accordingly dynamic multiplication of the developed electron image at the photo-sensitive electrode only and to prevent the electrons from normally reaching the grid electrode, a second grid electrode positioned on the opposite side of the photo-sensitive electrode from said first grid electrode, means for subjecting the dynamic multiplied electronic image to a second alternating electrostatic field having a frequency substantially less than that of said first electrostatic field by applying the second field to said second grid electrode to arrest dynamic multiplication of the electronic image after the predetermined number of bombardments, and means including said second field for projecting the dynamically multiplied electronic image upon a target electrode simultaneous with the arrest of dynamic multiplication.

11. An electronic device for intensifying the effect of an optical image comprising a photo-sensitive electron storage electrode capable of emitting secondary electrons, means for projecting and focusing an optical light image upon the electrode to produce an electronic image replica of the optical image by the emission of photo-electrons, a grid electrode positioned parallel to and spaced from the storage electrode, means for applying an alternating electrostatic field of high frequency between the storage electrode and the grid electrode, the intensity and frequency of the electrostatic field being such as to cause the emitted photoelectrons to repeatedly bombard only the storage electrode for a predetermined length of time to produce dynamic multiplication of the developed electron image at the storage electrode, means for subjecting the dynamic multiplied electronic image to a second alternating electrostatic field having a frequency substantially less than that of said first electrostatic field to arrest dynamic multiplication of the electronic image after the predetermined length of time, means including said second field for collecting the dynamically multiplied electronic image upon the grid electrode simultaneous with the arrest of dynamic multiplication, and means for utilizing the intensified charge image produced on the storage electrode.

12. An electronic device for intensifying the effect of an optical image comprising a photo-sensitive electron storage electrode capable of emitting secondary electrons, means for projecting and focusing an optical light image upon the electrode to produce an electronic image replica of the optical image by the emission of photo-electrons, a grid electrode spaced from and positioned parallel to the storage electrode, means for applying an alternating electrostatic field of high frequency between the storage electrode and the grid electrode, the intensity and frequency of the electrostatic field being such as to cause the emitted photoelectrons to repeatedly bombard the storage electrode for a predetermined number of times to produce dynamic multiplication of the developed electron image at the storage electrode only and to prevent the electrons from normally reaching the grid electrode, means for subjecting the dynamic multiplied electronic image to a second electrostatic field pulsating at a rate substantially less than that of said alternating electrostatic field to arrest dynamic multiplication of the electronic image after the predetermined number of bombardments, means for collecting the dynamically multiplied electronic image upon the grid electrode simultaneous with the arrest of dynamic multiplication, and means for scanning the storage electrode to produce an intensified image signal output in an external circuit.

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