Aug. 11, 1942. P. T. FARNSWORTH 2,292,437

ELECTRON IMAGE AMPLIFIER

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Fig. 1.

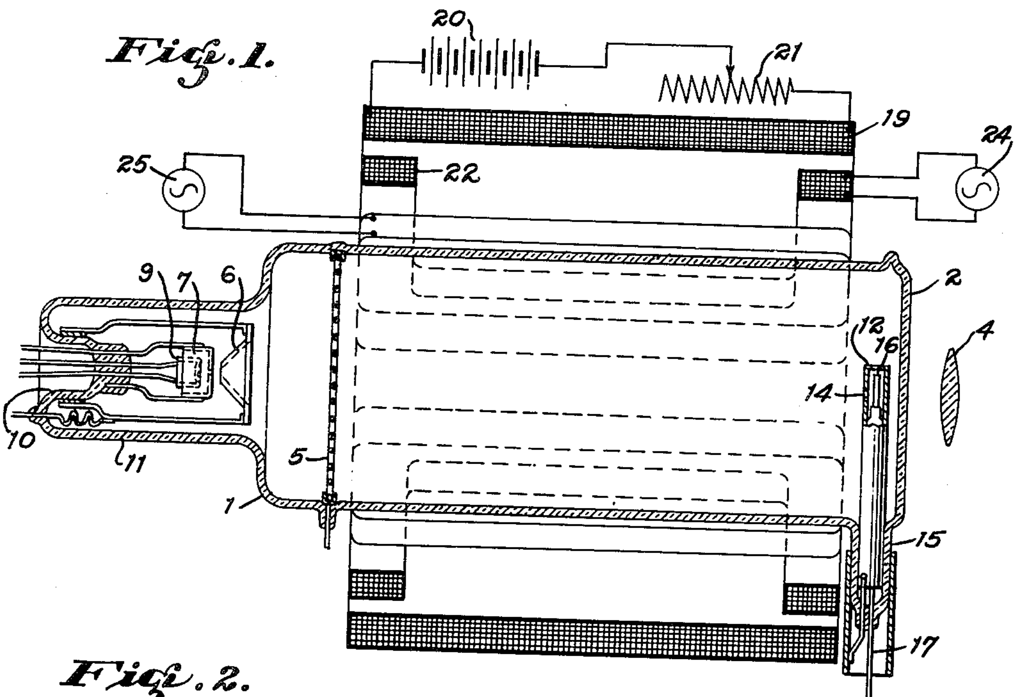

Fig. 2.

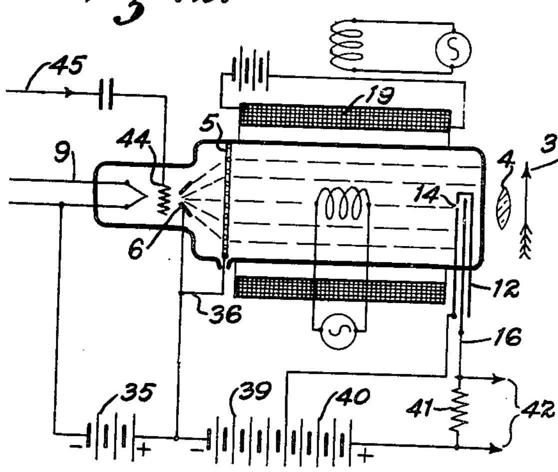

Fig. 3.

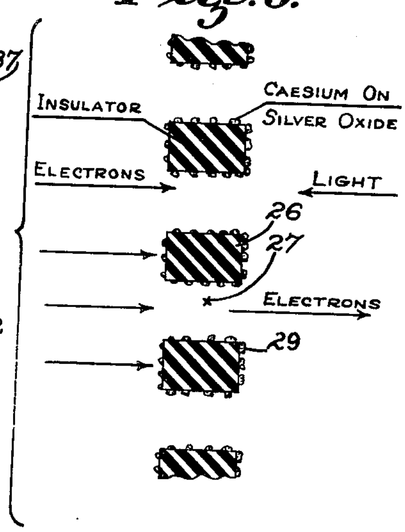

Fig. 4.

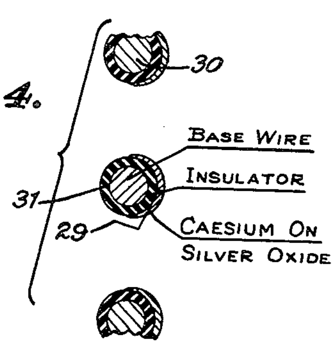

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Fig. 5.

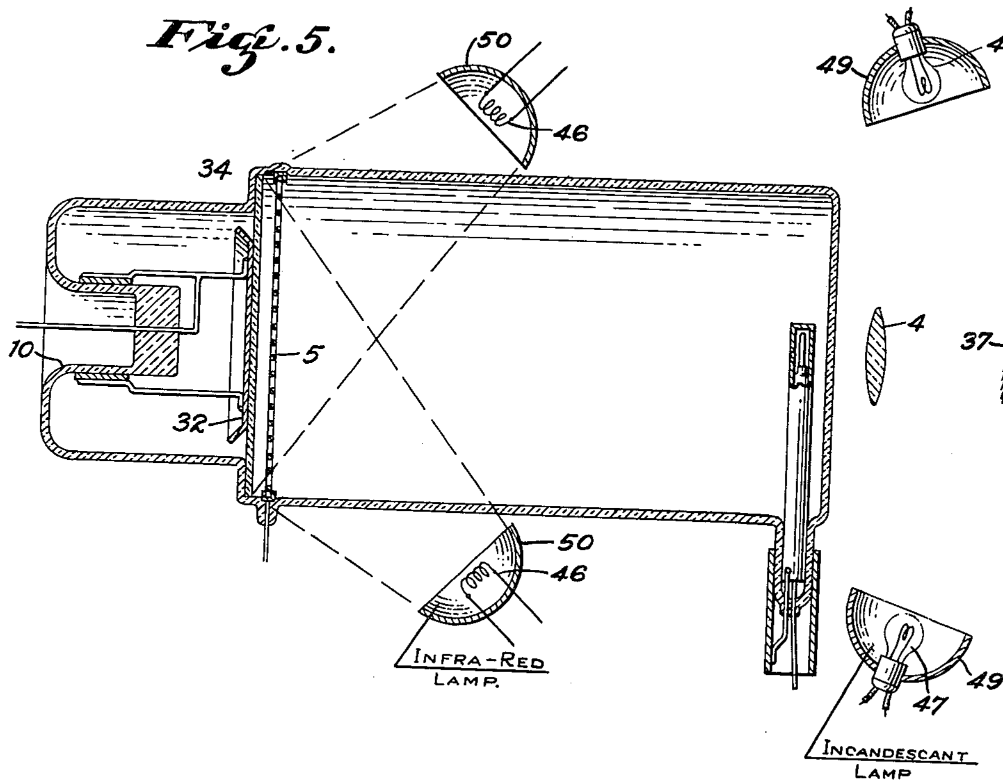

Fig. 7.

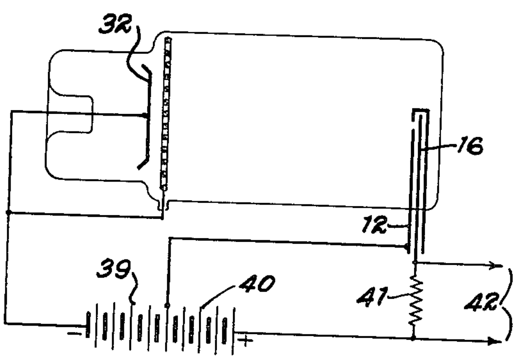

Fig. 6.

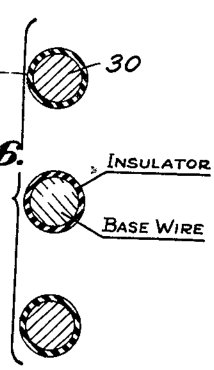

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Fig. 8.

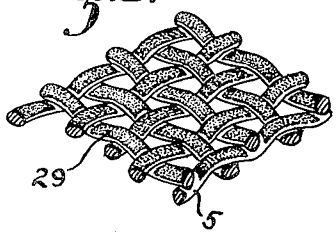


Fig. 9.

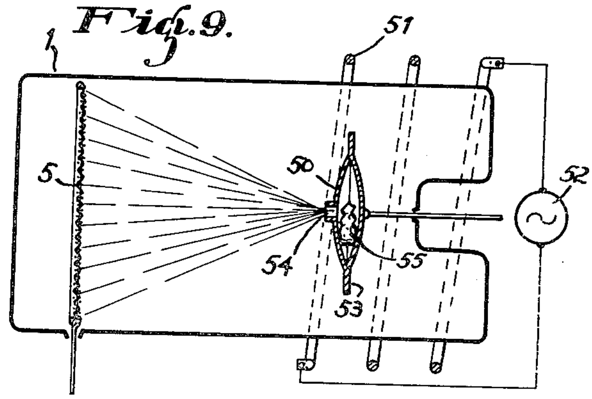


Fig. 10.

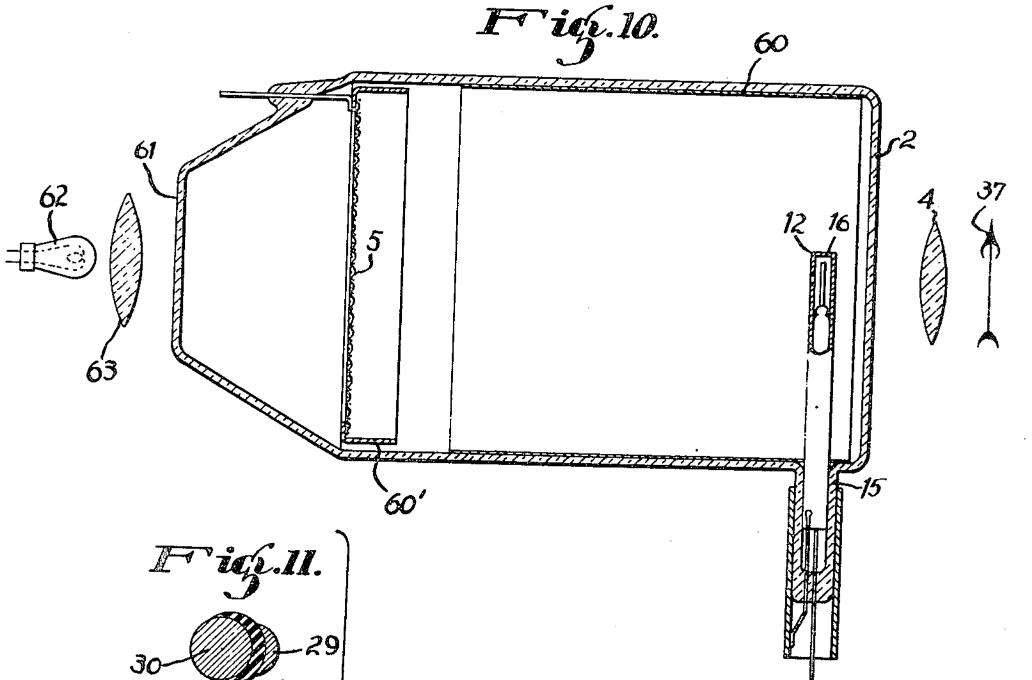
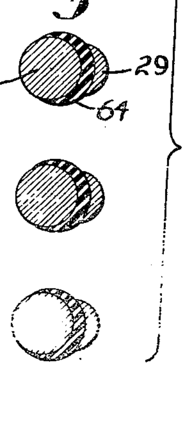


Fig. 11.



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Patented Aug. 11, 1942

UNITED STATES PATENT OFFICE

2,292,437

ELECTRON IMAGE AMPLIFIER

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Application July 1, 1935, Serial No. 29,242

25 Claims. (Cl. 178—7.2)

My invention relates to photoelectric devices, and more particularly to a method and apparatus for the electrical projection of pictures as in television, facsimile transmission, and reception, and the like, or in any other art where electron image amplification is desirable. My invention is peculiarly adaptable for use in connection with electrical scanning systems, either receiving or transmitting.

The broad method is applicable to both transmission and receiving cathode ray tubes, the specific embodiment described herein as utilizing my broad method being a transmission device, other embodiments of specific apparatus employing the broad method herein described and claimed being described and claimed in the other applications mentioned.

Among the objects of my invention are: To provide a method of electron image amplification utilizable either in a transmitting dissector tube or in a cathode ray receiving tube; to provide a method of increasing the sensitivity of photoelectric cells; to provide a method of increasing the sensitivity of television transmission cells; to permit the projection of television pictures by reflected light of ordinary intensity; to increase the electrical output of a photoelectric cell; to increase the electrical output of a television cell in order to provide satisfactory television signals without the use of complicated and sensitive amplifiers; to provide a television system wherein amplification of an electron image or any portion thereof may be accomplished without dissecting said image into picture elements; to provide a method of amplification for photoelectric purposes, particularly in television wherein the degree of amplification is limited by the extremely high frequencies which must be handled where the image is dissected before amplification; to provide a means and method whereby relatively large currents may be secured from a television transmitting cell; to provide an image amplifying structure which is simple and practical to fabricate; to provide an amplifier of photoelectric currents wherein extremely high amplifications may be obtained within the photoelectric cell itself; to provide a means and method for modulating an electron stream to produce an electron image; and to provide a means and method for modulating a uniform electron stream by photoelectrons created by an optical image.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

In my previous patents and applications for U. S. Letters Patent, as follows:

Patent No.	Issued
1,773,980	Aug. 26, 1930
1,844,949	Feb. 16, 1932
1,941,344	Dec. 26, 1933

Serial No.	Filed
668,066	Apr. 26, 1933, and others.

I have described television transmitting apparatus and systems wherein an optical image of the object or picture field is thrown upon a photo-sensitive cathode and the emitted electrons are accelerated and focused to form an electron image. By electron image I mean a plane through which the electron stream passes, the electron density of which varies spatially across the stream in the same manner as the illumination density varies across the optical image. In other words, the electron density values represent spatially, the illumination of the picture field.

The electron stream forming this image may be deflected by means well known in the art, but preferably, by magnetic means to pass over an aperture in such a manner as to effect the scanning of the image. Selected portions of the electron stream passing through the aperture are collected to form a picture current or train of picture signals which may be amplified and modulated upon a radio wave, or transmitted by wire. This method of television transmission offers the advantage of having no moving parts and of being suitable for the electrical projection of pictures having any desired fineness of detail.

The principal weakness of this method lies in the fact that only a relatively small portion of the electrons emitted from the total photoelectric area is used at any given instant and at the present time photoelectric emission is relatively small in intrinsic value. Therefore, the highest possible sensitivity must be obtained from the photoelectric surfaces and even then high gain amplifiers are necessary in order that satisfactory picture currents can be obtained. With small output currents, attempts to amplify the signals above a certain level bring in background noise, Shottke effect and other ordinarily negligible factors which tend to make the amplified picture currents unsatisfactory and distorted, and the received picture lacking in the detail which it would have if such interference were not present.

In the present invention the fundamental principle of my previous invention is retained and other desirable features added. An electron image corresponding to the optical image is formed and is thereafter treated as before. In the present device, however, the image has a considerably higher average value than in the previous device because of the fact that space charges are formed, the electrons in the space charge being released by the optical image. I am therefore able to produce electron images with the present device which are far more powerful than the electron images heretofore produced and under these circumstances, when the image is scanned, picture currents of much greater amplitude are directly obtained, thereby eliminating high gain amplifiers with their objectionable features.

As for receiving tubes, I am able to create a charge image and then utilize the charge image to control a uniform electron stream directed against a luminescent screen.

In the broad aspect disclosed herein, I form a charge image representing part or all of an optical image and then utilize the charge image produced to effect a uniform electron flow to form an electrical image in accordance with the charge image. The electrical image may be in the form of an electron image which may then be dissected into successive elementary areas thereof to form a train of television signals or may be utilized directly to re-form an optical image, as in a receiver. The electrical image may also be in the form of a current flow derived from the uniform electron stream by the action of the charge image, this flow being varied in time and amplitude distribution in accordance with the spatial and amplitude arrangement of the charges, thus producing a train of picture signals.

In the specific embodiments of my method presented here, I prefer to form a stream of electrons in space having a uniform cross sectional intensity. I then create a space charge in this stream, thus storing energy. The energy in the space charge is then released by the formation of a charge pattern in space representing in the intensity of various elementary areas thereof the spatial light intensity of the object or picture field.

The uniform electron stream is passed through the charge image and thus is modulated and energy in the space charge released to form an electron image which then may be treated exactly as if the electron image were emitted directly from a photosensitive surface without storage of energy. In other words, I utilize true space charge amplification instead of depending upon an electron supply coming directly from an energized cathode.

Describing my invention broadly in terms of apparatus, there are several means by which the above method may be practiced. One means, for example, is the use of an electron gun to supply an electron stream of uniform cross sectional density, this stream being directed against a screen having an insulating surface upon which a photoelectric mosaic is deposited. Certain electrons in the stream charge the mosaic and a space charge is developed. An optical image is then focused on the mosaic which emits electrons and the various portions of the mosaic will thereupon assume varying potentials in accordance with the illumination. Electrons from the uniform stream which are drawn through the grid are modulated by the mosaic charges to form an electron image which is then dissected in the usual manner.

Another means by which the same result, namely, that of an amplified electron image, may be obtained, is by using a photoelectric surface as a source of two electron streams; i. e., electrons falling into two velocity categories. One, a category containing low velocity electrons produced by uniform illumination of the cathode of the surface by light within a definite wavelength range, the electrons in the other category being produced by the light of an optical image focused on the same surface from an object illuminated with light having an entirely different wavelength range. If the latter range contain a large component of the shorter wavelength, the electrons emitted thereby will have higher velocity.

Placed adjacent the photoelectric surface is a grid or apertured member, either wholly of insulating material or having an insulated surface, preferably the latter, which charges up by collection of the low velocity electrons so that a space charge develops between the grid and the photoelectric surface. The higher velocity electrons, however, due to the excitation by the optical image, charge up the grid with a charge image representing spatially the optical image, and when the electrons are drawn through the grid by an energized anode, modulation of the low velocity component occurs, thus giving rise to an electron image amplified because of the storage of electrons in the space charge.

Various other modifications and applications of my invention will be apparent to those skilled in the art and for other broad aspects of my invention I prefer to refer to a detailed description of several preferred embodiments of my invention as shown in the drawings, of which

Figure 1 is a longitudinal sectional view of a television dissector tube provided with focusing and scanning coils, together with means for projecting an optical image therein.

Figure 2 is a diagrammatic circuit reduced to lowest terms showing how the device of Figure 1 may be operated to produce a train of television signals.

Figure 3 is a detailed sectional view of one form of grid.

Figure 4 is a detailed view in section of another form of grid.

Figure 5 is a cross sectional view of another form of dissector tube showing differential illumination of the photosensitive surface therein.

Figure 6 is a cross sectional view of a portion of the control grid of the tube shown in Figure 5.

Figure 7 is a diagrammatic circuit showing how the tube of Figure 5 may be operated.

Figure 8 is a perspective view of a mesh mosaic.

Figure 9 is a diagrammatic view of apparatus used in forming a silver mosaic.

Figure 10 is a longitudinal sectional view of another modification of my invention.

Figure 11 is a cross sectional view of a composite grid having two photoelectric surfaces.

Describing the apparatus in detail, without reference to the operation thereof, which will be taken up later, and referring directly to the modification shown in Figure 1, an envelope 1 is provided at one end with a transparent window 2 in front of which is placed an optical system 4 in such a manner as to focus an optical image of an object upon a charge storage electrode or grid 5 positioned adjacent the opposite end of the tube. On the other side of this grid there is positioned a wide angle electron gun comprising a cone-shaped apertured anode 6, a control grid 7, and preferably an indirectly heated cathode 9. This assembly is preferably mounted on a stem 10 in an extension arm 11 of the envelope.

Adjacent the window end of the tube an apertured anode assembly is provided comprising a finger tube 12 having an aperture 14 facing the grid 5 mounted securely in an anode extension 15 of the envelope. Mounted inside of the finger 12 is a collecting plate 16, positioned immediately back of the aperture 14, mounted on a lead 17.

The tube is preferably provided with a focusing coil 19 energized by a focusing source 20 under the control of a variable resistor 21 which provides a longitudinal magnetic field between the grid 5 and the scanning aperture 14 for the purpose of maintaining the electron image in proper spatial relationship during its passage therebetween.

The tube is also provided with exterior coils 22 and 23 positioned substantially at right angles to each other for moving the electron image in two directions over the scanned aperture 14, the magnetic fields of these coils being formed by energization by scanning oscillators 25 and 24 respectively.

Several different types of grid structures may be used with this device, but in any case the grid member 5 is apertured preferably with an area devoted to the apertures equal to that of the supporting material. For example, I may make, in certain cases, my grid entirely of insulating material as shown in Figure 3. Here the insulator 26 is provided with apertures 27 and is also provided with a layer of caesium on silver oxide 29. This layer is formed in the usual manner for forming mosaic photoelectric surfaces, the silver being deposited thereon in such a manner that it congeals in droplets so that a mosaic is formed with the caesium formed thereon leaving separate photoelectric islands more or less uniformly insulated one from the other, as is well known in the art.

Another form of grid is shown in Figure 4 where the base material 30 is a conducting material such as nickel wire, for example, which has deposited thereon a layer of insulating material 31 and over the insulating material a mosaic 29 of caesium on silver oxide is formed. The preferred way of forming the grid of this latter construction is to utilize a mesh screen of nickel, for example, having rather larger spaces between the grid wires than the area of the wires themselves and smoking the entire screen with burning magnesium until the wires are covered with magnesium oxide to a point where the spaces are approximately equal to the area of the composite member. Caesium on silver oxide is then formed upon the magnesium base to form the mosaic.

When I desire to form a mosaic on an insulating surface of a mesh grid fabric, I have found that it is not necessary to follow the complicated and uncertain process above referred to.

In Figure 9 I have shown a preferred apparatus for forming a mosaic on the mesh grid. The grid is covered with insulating material, at least on the side facing the optical image, preferably by smoking with magnesium oxide as above described, and silver is evaporated thereon preferably from substantially a point source 50, a convenient means being the application of eddy currents from a coil 51 energized by an oscillator 52 to a container 53 having an aperture 54 facing the grid and enclosing silver metal 55. The silver, being evaporated in vacuo, travels in straight lines and therefore casts sharp shadows. As the individual wires in the mesh alternately pass over and under the wires at right angles to them, the silver deposit is separated into small rectangles the size of the mesh. No silver is deposited under the overhang of the wires, and not only do I obtain substantially perfect insulation between the silver islands, but I am able to accurately control the size of the islands by changing the mesh of the fabric. A mosaic of this type is shown in Figure 8 in perspective and in Figure 11 in cross section.

In practice, a completely opaque film of silver has been evaporated onto a grid member, and the resistance between two contacts $\frac{1}{8}$ of an inch apart on such a screen measured to be in excess of 10^{14} ohms, showing the extremely good insulation between islands. I prefer, however, to utilize only a fairly thin film of silver, and then when the tube is formed this film is completely oxidized, utilizing, as is customary, a radio frequency discharge in pure oxygen.

I also prefer to completely clean up the excess caesium after the tube is formed. There are a number of ways of accomplishing such a clean-up but I prefer to include within the tube, either connected to the cathode or the anode, a fairly large surface of pure silver which may be oxidized with a fairly heavy coating. After the tube is formed, therefore, this surface is capable of absorbing a large amount of caesium, even after the thin film of silver on the grid has taken up its maximum.

The preferred procedure, therefore, after the surfaces it is desired to sensitize have reached maximum sensitivity, is to lower the temperature somewhat and bake the tube out in this lower temperature for a sufficiently long time until the excess of caesium within the tube is all taken up by the accessory oxidized silver surface.

Another modification of my invention is shown in Figure 5 and in this case a photoelectric emitter has been substituted for the electron gun, the photoelectric emitter in this case comprising preferably a continuous photoelectric surface 32 formed on a base member 34, preferably a silver plate. This plate is supported on the stem 10 in any customary manner. The grid 5 is then positioned immediately in front of and parallel to the photoelectric surface, and in this case the grid 5 comprises preferably a conductor having an insulating surface. While the entire grid structure may be an insulator, I prefer to utilize the conducting base 30 provided with a relatively thin layer of magnesium oxide formed thereon as above described, and in this case I do not place upon the insulator any photoelectric material.

Referring directly to the modification shown in Figure 1 connected as in Figure 2 and assuming that it has a grid as shown in Figure 3; in other words, a grid which is completely an insulator, the anode 6 of the electron gun is connected to the cathode in series with an anode battery 35 and the cathode 9 is energized in the usual manner so that the entire grid structure 5 will be bombarded with a suitable amount of 100 to 300 volt electrons. The grid will then assume a negative charge just sufficient to prevent these electrons from striking it, thus forming a space charge immediately back of the grid. The potential of the grid, that is, the normal uniform potential of the grid, will be largely determined by a small number of electrons having the highest velocity and due to leakage in the grid structure, the entire grid will assume a uniform charge equilibrium.

Inasmuch as the grid in this instance is entirely formed of insulating material, the uniform grid charge in the structure shown in Figure 3 will be slightly higher than in the structure shown in Figure 4, where the insulating layer is formed on a base wire 30, as I prefer to connect this base wire to the anode 6 by a connection 36. In this case, the negative charge, because of greater leakage opportunity will be slightly less than when the entire grid is formed of insulating material.

After the grid has assumed a uniform negative charge and the space charge has been formed behind the grid due to this negative charge, an optical image of an object 37 is focused by means of optical system 4 on the side of grid 5 opposite to that being bombarded. This optical image falls on the mosaic photoelectric layer 29 and causes emission therefrom, the electrons being drawn toward anode 12, those of some particular elementary area entering aperture 14 and being collected on collecting plate 16. In order to create electron traversal of the tube, anode 12 is maintained at a positive potential by means of an anode battery 39 and the collecting plate 16 is maintained at a potential positive to anode 12 by collecting source 40. The difference between the number of electrons collected by the collecting plate 16 and finger 12 passing through output resistor 41 and thus creating a potential available for further use in output leads 42.

When electrons are emitted from the mosaic surface due to the action of the image light, they will of course be emitted in proportion to the intensity of the light falling on the individual mosaic islands and the islands will become more or less positive due to the loss of electrons in accordance with the light striking them. This results in lowering the negative potential of different portions of the grid to a new point of equilibrium and results in the formation of a charge image on the grid representing in intensity the light intensity of the image. Electrons from the space charge developed back of the grid 5 are thus able to be drawn through the grid toward the anode 12 and due to the fact that the number drawn through at any particular elemental area is controlled by the charges on elemental areas of the grid, there will be formed in space between the grid and the anode, an electron image. This electron image is maintained in spatial relationship by the focusing coil 19 and is scanned across aperture 14 by the moving magnetic fields developed by the scanning coils and generators positioned as previously described.

If desired, the output of the electron gun can be modulated at radio frequencies by means of a gun grid 44 supplied with a radio frequency modulation voltage through input lead 45. This allows output amplification with this type of amplifier and in this manner the D. C. component can be preserved and a single side band generated if desired, as will be apparent to those skilled in the art.

I have thus produced by a storage of electrons in a space charge, an electron image of greatly increased intensity over one which could be produced by means of light falling directly upon a photoelectric surface, the emission from this surface being scanned as in my previous inventions. The greatly increased output which appears across output resistor 41 may be amplified with far less amplification and with consequent quietness and freedom from interference and distortion.

Another apparatus for producing electron storage for the purpose of providing an amplified electron image is shown in Figure 5 and connected as shown in Figure 7. In this case, I do not use an electron gun for the source of electrons forming a uniform electron stream, but I prefer to use a flat photoelectric cathode 32.

This cathode is preferably formed as is customary in the art on a silver plate 34 by oxidation and the deposition of caesium until maximum sensitivity to light is obtained and is preferably not a mosaic. The cathode is then flooded with infra-red and red light from lamps 46—46 until the cathode develops in a specific instance for example, 100 microamperes current. Grid 5 in this case is not photoelectric, but is preferably composed of a base wire 30 of nickel having an insulating coating thereon preferably of magnesium oxide formed as above described.

In operation, the object 37 is illuminated solely by sunlight, for example, or by incandescent or arc lamps 47, care being taken that none of the white light reaches cathode 32 except that which is reflected from the object 37 and focused on the cathode 32 by lens 34. This is accomplished in practice by the use of reflectors 49—49 on the white lights and as it is also desirable that no red light illuminate object 37 reflectors 50—50 are used on the red lights, these reflectors being so placed that the light is directed in one case on the cathode alone and in the other case on the object alone. The tube of Figure 5 may be hooked up as shown in Figure 7, the scanning and focusing coils being omitted from the sketch in the interests of simplicity, it being understood that they are to be used in the operation of the device.

Cathode 32 is connected with anode finger 12 in series with the anode source 39. The usual collecting source 40 is connected to the collecting plate 16, the output appearing across output resistor 41 in output leads 42 exactly as in the previous instance. Thus, there will fall upon the cathode surface 32 two different illuminations. One, a long wavelength uniform illumination from the red lamps 46 which causes a uniform emission of low velocity electrons from the cathode. The other illumination is an optical image of light having a wavelength range containing short wave-lengths which will produce electrons from cathode 32 falling into a different velocity category and having higher average velocities.

Thus there will be emitted from cathode 32 electrons falling into two velocity categories. One category, made up of a uniform compo nent of low velocity electrons, the other category, a non-uniform electron image of higher velocity electrons. The grid, assuming that no optical image is thrown upon the cathode, will assume a negative charge because electrons reaching the grid collect upon the insulating layer and leak off to the base wire, thus reaching an equilibrium value at perhaps in the neighborhood of three-quarter's of a volt. This will form a space charge back of the grid.

When this equilibrium is reached, that is, the equilibrium due to the bombardment by low velocity electrons, the charge on the grid will be uniform throughout. When, however, the optical image reaches the cathode surface, electrons of higher velocity are emitted, which, due to their higher velocity can reach the grid and thus charge the grid more negatively at those points where they do reach it and by an amount in proportion to the numbers reaching it. Inasmuch as the number of high velocity electrons reaching the grid at any elementary area thereof will be dependent upon the illumination of the cathode on corresponding elementary areas thereof by the optical image, it can be seen that a charge pattern is built up upon the grid, this charge pattern modulating the electrons passing through the grid due to the pull of the anode 12, thus forming in the space between the grid and the anode a new electron image of higher intensity which then may be maintained throughout the traversal of the tube in spatial relationship by means of the usual focusing coil and moved across the aperture 14 by the scanning coils to produce a television picture current of greater intensity. In this instance, the grid becomes more negative due to the action of the optical image emission, and modulation is downward.

I have found that by the building up of a space charge behind the grid and then forming a charge pattern on the grid in accordance with an optical image pattern, that I have increased the overall sensitivity of the dissector tube over one thousand times, thus decreasing enormously the amount of amplification necessary in the circuits utilized to handle and make useful the signal train produced by scansion.

In all of the specific apparatus embodiments employing my method herein described, a new charge pattern is developed on the control member with each new shift of the light pattern and the action of the tube is independent entirely of scansion. If a shift of the light pattern due to a movement of the object occurs during scansion, the picture produced toward the end of the scanning cycle is simply an intermediate picture between that which was shown at the beginning of the scanning cycle and that which is to come on the following scanning cycle. Even when objects move with the highest speeds customarily occurring within the perception of the human eye there is plenty of time for the charge pattern to develop as such movements are relatively slow and the period required for the development of the charge pattern exceedingly short. Thus, the readjustment of the charge pattern to motion is always effective before scansion and if motion should occur exactly at the instant of scansion, the charge on the elementary area would be that of the previous intensity before motion occurred as it would be obviously unusual for any fortuitious combination of motions to take place in synchronism with the scanning motion for any perceptible length of time.

My invention also includes the formation of a composite cathode utilizing the same method. In other words, the grid and the photo cathode are combined so that the same action occurs. Theoretically, if a fine insulating powder is deposited directly on the cathode in such a manner that there are spaces between the powder units, charges would be formed on the insulating upper portions of the powder which would be able to modulate low velocity electrons due to the long wavelength illumination. It would, however, be rather difficult in practice to form the cathode surface under these circumstances and the insulating powder would be likely to become contaminated with caesium and perhaps become conductive. I have, however, been able to produce a composite cathode by using an extremely thin coating of insulating powder, and oxidizing the composite surface by means of a glow discharge in argon after formation of the caesium surface, to clean up all conductive metal overlying the insulating material. When such a composite cathode is formed, I prefer to utilize a small amount of radio frequency excitation applied to the cathode in operation in order to increase the number of electrons striking the insulator.

Another method by which a composite cathode may be made is the formation of the cathode utilizing caesium monoxide as an insulator thereon. When a silver plate having a monoxide layer is processed to form the photoelectric surface, the caesium distilled thereagainst will combine with the caesium monoxide to form caesium trioxide, which is also a good insulator.

Thus, in both cases, a photoelectric surface will be formed having a plurality of insulating islands thereon spaced to allow electron emission therebetween, charges from the emission being formed on the insulating islands and controlling the flow as has been described for the grid in previous paragraphs.

Still another modification capable of practice in my invention is shown in Figure 10. Here, the photoelectric cathode 32 and the grid 5 are combined into a single unit all formed on the grid screen 5. This member is shown in cross section in Figure 11.

In the embodiment shown in Figure 10 the collecting finger assembly 12—16 is mounted in one end of the tube and surrounded with a nickel film 60 preferably connected to finger 12, and the grid screen 5 is mounted facing the opening in the finger 12. In this case I have also provided the envelope with a second transparent window 61 for directing onto the side of the screen 5 opposite the finger the flooding light from a source 62 through a flood lens system 63.

The grid 5 in this instance is formed as shown in Figure 9. The foundation or base wire 30 is smoked so that the insulating material, such as magnesium oxide 64 for example, is deposited only on one side of the grid, and in this instance I prefer to make the foundation material of pure silver wire. The insulating material is then exposed to silver evaporation as before described, so that a mosaic is formed upon the insulating surface. The silver surface is then sensitized as previously described, and at the same time the exposed silver surface of the grid wires on the other side of the grid will also be formed. Thus there will be on the grid two completely separate photoelectric surfaces; one facing the flooding light source 62 being connected together to form a continuously conductive surface, and the other, facing the anode finger 12, a photoelectric mosaic surface.

In this particular embodiment I also prefer to provide the grid **5** with a cylindrical wall extension **60'**, the edges of which extend toward but do not meet film **60**. The combination of film and extension constitute an electrostatic lens which helps to maintain the edges of the electron image in sharp focus. In many cases it may be desirable to apply the same type of focusing to the other embodiments described in this application in addition to the focusing means shown.

When the continuously conductive surface is illuminated, the light, which in this case need not be of any different spectral characteristics from that in the optical image, causes electrons to be emitted on the back side of the grid, uniformly all over the entire surface, thus forming an electron source, the emission therefrom creating a space charge on the back of the grid. On the front side of the grid, however, the side where the photoelectric surface is illuminated with light from the object, a charge image representing the optical image projected onto this surface is formed on the mosaic which modulates electrons being emitted from the rear surface and drawn through the grid by the voltage on the finger **12**. The electrons passing through the grid form in space, between the grid and the collecting assembly, an optical image which may be scanned in the usual manner.

This particular type of tube is practical to build and is desirable for a number of reasons. The amplification is high and the uniformity of the rear discharge is such that all portions of the mosaic control practically the same number of electrons. It is not necessary to use infra-red light on the rear surface as the photoelectric surfaces are separated, and the light from the two sources fall only on their own proper surfaces. Furthermore, one of the principal advantages of this type of tube is that the mosaic elements draw very little current, because of their location on the opposite side of the grid from the source of the flooding electrons.

The response period of this tube may be regulated in several ways. Pure magnesium oxide has such a long leakage time that it is desirable to reduce it either by adding to the magnesium oxide other materials giving less perfect insulation or, as is quite practical to do, to leave a very small residual amount of gas in the tube, the amount of gas left, of course, controlling the discharge time of the mosaic elements. The leakage time may be reduced to the proper point by the controlling amount of residual gas, which has been found too small to affect the electron image in any way or to blur or distort the final television signal when of the proper amount to control the leakage within the limits of the picture frequency.

It should be pointed out that in every embodiment shown a charge image representing the optical image is formed, and this charge image is then used to modulate a uniform stream of electrons, the resultant stream being dissected to form a train of television signals.

I have shown modifications where the charge image is formed on a photoelectric mosaic, and on a surface of insulating material, this surface either having a conductive base, or not, as desired. I have shown that the source of the uniform electron stream may be either a thermionic or a photoelectric source, and I have described a composite grid structure where a continuously conductive photoelectric surface is utilized on one side of the grid, and a photoelectric mosaic utilized on the other side on which a charge image may be formed to control electrons from the first surface.

In all cases high amplifications are obtained, the resultant electron image having a far greater intensity than an electron image originating directly from a photoelectric surface.

I claim:

1. The method of producing an electron image which comprises the steps of utilizing light of a first spectral range to create a uniform stream of relatively low velocity electrons, utilizing light of a second different spectral range to create a non-uniform stream of relatively high velocity electrons, the non-uniformity representing electron density values in image relation, and modulating said uniform stream by charges produced in spatial relation with and by said non-uniform stream.

2. The method of producing an electron image which comprises the steps of utilizing light of a first spectral range to create a uniform stream of relatively low velocity electrons, creating a space charge in said stream, utilizing light of a second spectral range to create a non-uniform stream of relatively high velocity electrons, the non-uniformity representing electron density values in image relation, and changing the value of said space charge in accordance with said non-uniform stream.

3. The method of producing an electron image which comprises creating an electron stream of uniform cross sectional density, creating a uniformly distributed space charge therein, creating a charge image in space spatially representing the light values of an object, applying said charge image to said space charge to create a non-uniform electron stream having elemental cross sectional area densities corresponding to the light values of elemental picture areas, and successively collecting electrons in elemental areas of said non-uniform stream.

4. The method of electron image amplification which comprises forming an electron flow in space, forming a charge image in space of a picture field, passing said flow through said charge image to produce an electron image of said field, and scanning successive elementary areas of said electron image to produce a train of picture signals.

5. The method of electrical image transmission which comprises projecting the light of a plurality of elemental areas of an image on an apertured photosensitive member to produce an electrical image comprising a plurality of separate and distinct electrostatic charges on isolated areas of said member, the value of each charge being dependent upon the intensity of the light received from the corresponding elemental areas of the picture projected on said member, creating an electron flow, controlling the flow in accordance with the charges, and scanning successive elemental areas of the controlled flow to produce a train of signals.

6. The method of electrical image transmission which comprises projecting an optical image on to an apertured and discontinuous light sensitive member to form a charge image thereon corresponding in elemental charge values to elemental light values of said optical image, controlling an electron flow of picture area by said charge image, and deriving a picture signal from the controlled electron flow.

7. The method of electron image formation which comprises uniformly illuminating a photo-

sensitive surface with light of relatively long wavelength to produce a stream of relatively low velocity electrons, utilizing a portion of said electrons to produce a uniform space charge in said stream, illuminating said surface with light of relatively short wavelength spatially conforming with the illumination of an object to produce a stream of relatively high velocity electrons, and utilizing said latter electrons to modify said space charge to produce an electron image spatially conforming to the illumination of said object.

8. The method of producing an electron image which comprises illuminating a photoelectric surface with light of differing wavelengths to produce an electron stream having components of higher and lower velocities, and utilizing the energy of one of said components to modify the other component.

9. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, an apertured member in the path of said flow, means for producing on said member a charge image spatially representing the spatial illumination of an object, and means for successively collecting electrons in elementary areas of the electron stream passing through said apertured member.

10. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, an apertured member positioned in the path of said flow, said member having a surface of insulating material a mosaic of photoelectrically sensitive material upon said surface, means for focusing an optical image upon said mosaic to produce emission therefrom thereby forming a charge pattern on said member, and means for directing said flow through said aperture to form an electron image in space.

11. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, an apertured member positioned in the path of said flow, said member having a surface of insulating material, a mosaic of photoelectrically sensitive material upon said surface, means for focusing an optical image upon said mosaic to produce emission therefrom thereby forming a charge pattern on said member, means for directing said flow through said aperture to form an electron image in space, and means for collecting electrons in successive elementary areas of said electron image.

12. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, an apertured member positioned in the path of said flow, said member having a surface of insulating material, a mosaic of photoelectrically sensitive material upon said surface, means for focusing an optical image upon said mosaic to produce emission therefrom thereby forming a charge pattern on said member, means for directing said flow through said aperture to form an electron image in space, and an apertured anode energized to direct said electron image thereagainst, and an electrode behind the aperture in said anode to collect the electrons passing therethrough.

13. An electron image amplifier comprising an envelope containing means for generating a spatially uniform electron flow, an apertured member positioned in the path of said flow, said member having a surface of insulating material, a mosaic of photoelectrically sensitive material upon said surface, means for focusing an optical image upon said mosaic to produce emission therefrom thereby forming a charge pattern on said member, means for directing said flow through said aperture to form an electron image in space, an apertured anode energized to direct said electron image thereagainst, and an electrode behind the aperture in said anode to collect the electrons passing therethrough, and means for moving said image over said aperture to scan elemental areas thereof.

14. An electron image amplifier comprising an envelope containing a photoelectric surface, an apertured member positioned adjacent and parallel to said surface and spaced therefrom, said member being provided with a coating of insulating material, means exterior of said envelope for uniformly illuminating said photoelectric surface with light having a relatively narrow wavelength range adjacent the red end of the spectrum, means independent of said first mentioned means for illuminating an object with light having a relatively wide wavelength range within the remainder of the spectrum, and means for focusing an image of the object on said photoelectric surface simultaneously with the illumination by said first mentioned means.

15. An electron image amplifier comprising an envelope containing an apertured grid, said grid having a photoelectric surface on opposite faces thereof, one of said surfaces being a mosaic each portion of which is insulated from the other and from the other surface, means for projecting an optical image on said mosaic to cause electron emission therefrom, means for uniformly illuminating the other surface, and means for drawing electrons from the uniformly illuminated surface through the grid apertures.

16. An electron image amplifier comprising an envelope containing an apertured grid, said grid having a photoelectric surface on opposite faces thereof, one of said surfaces being a mosaic each portion of which is insulated from the other and from the other surface, means for projecting an optical image on said mosaic to cause electron emission therefrom, means for uniformly illuminating the other surface, means for drawing electrons from the uniformly illuminated surface through the grid, and means for collecting the electrons passing therethrough.

17. An electron image amplifier comprising an envelope containing an apertured grid, said grid having a photoelectric surface on opposite faces thereof, one of said surfaces being a mosaic each portion of which is insulated from the other and from the other surface, means for projecting an optical image on said mosaic, means for uniformly illuminating the other surface, means for drawing electrons from the uniformly illuminated surface through the grid to form an electron image in space, and means for collecting successive elemental areas of said image.

18. An electron image amplifier comprising an envelope containing an apertured grid, said grid being a mesh fabric of conducting material, a layer of insulating material on one side only of said grid, the opposite side being exposed, a photoelectric misaic on said insulation layer, a photoelectric surface on said exposed side, means for projecting an optical image on said mosaic, means for uniformly illuminating the opposite side, and means for drawing electrons from the opposite side through the apertures and past the mosaic.

19. An electron image amplifier comprising an

envelope containing an apertured grid, said grid being a mesh fabric of conducting material, a layer of insulating material on one side only of said grid, the opposite side being exposed, a photoelectric mosaic on said insulation layer, a photoelectric surface on said exposed side, means for projecting an optical image on said mosaic, means for uniformly illuminating the opposite side, means for drawing electrons from the opposite side through the apertures and past the mosaic, and means for maintaining the electrons passing through in electron image relation.

20. An electron image amplifier comprising an envelope containing an apertured grid, said grid being of mesh fabric of conducting material, a layer of insulating material on one side only of said grid, the opposite side being exposed, a photoelectric mosaic on said insulation layer, a photoelectric surface on said exposed side, means for projecting an optical image on said mosaic, means for uniformly illuminating the opposite side, means for drawing electrons from the opposite side through the apertures and past the mosaic, and means for collecting successive elemental areas of said image.

21. In an image transmitting system, a perforated photo-electric mosaic screen, means for focusing a light image thereon to form an electron image on the screen, an electron gun positioned so as to pass electrons through all openings in the mosaic screen, an electrode positioned on the opposite side of the mosaic screen from the electron gun and an electron lens between the mosaic and the electrode to focus the electron stream in the plane of the electrode.

22. An electric discharge tube comprising an evacuated envelope having therein a thermionic cathode for producing an electron beam of extended cross-sectional area, means for heating said cathode, an electrical image utilizing element, and a mosaic of photo-electric elements electrically insulated from each other and positioned between said cathode and said utilizing element, said mosaic being of grid-like structure whereby electrons may pass therethrough from said cathode to said utilizing element.

23. An electric discharge tube comprising an evacuated envelope having therein a source of electrons forming a beam of extended cross-sectional area, a target electrode of small area compared with said beam area, a mosaic of discontinuous photo-electric elements positioned between said cathode and said target, said mosaic being of grid-like structure whereby electrons may pass therethrough from said cathode to said target, means for focusing the electrons leaving said cathode, and means for scanning said target with said beam.

24. An electric discharge tube comprising an evacuated envelope having therein a source of electrons forming a beam of extended cross-sectional area, a screen electrode having an opening therein, a mosaic of discontinuous photoelectric elements positioned between said cathode and said screen electrode, said mosaic being of grid-like structure whereby electrons may pass therethrough from said cathode to said screen, means for focusing electrons leaving said cathode, and means for scanning said opening with said beam.

25. An electric discharge tube comprising an evacuated envelope having therein a thermionic cathode for producing an electron beam of extended cross-sectional area, means for heating said cathode, an electrical image utilizing element, a mosaic of photo-electric elements electrically insulated from each other and positioned between said cathode and said utilizing element, said mosaic being of grid-like structure whereby electrons pass therethrough from said cathode to said utilizing element, and means for focusing the electrons leaving said cathode.

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