May 24, 1938.

P. T. FARNSWORTH

2,118,186

IMAGE RECEIVING TUBE

Filed July 15, 1935

3 Sheets-Sheet 1

Fig. 1.

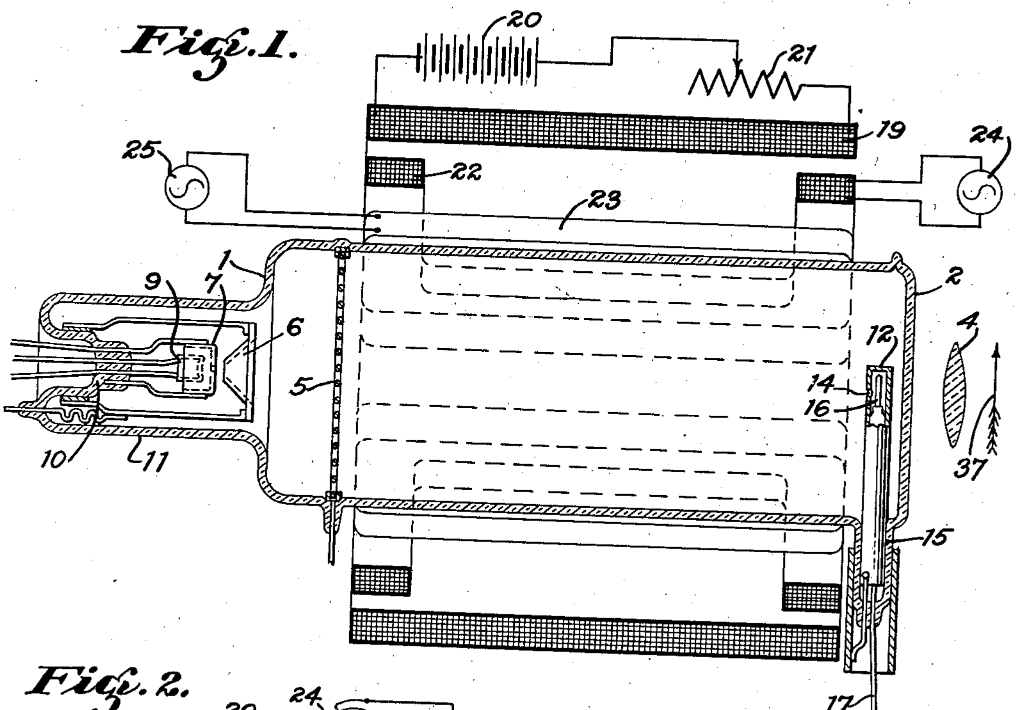


Fig. 2.

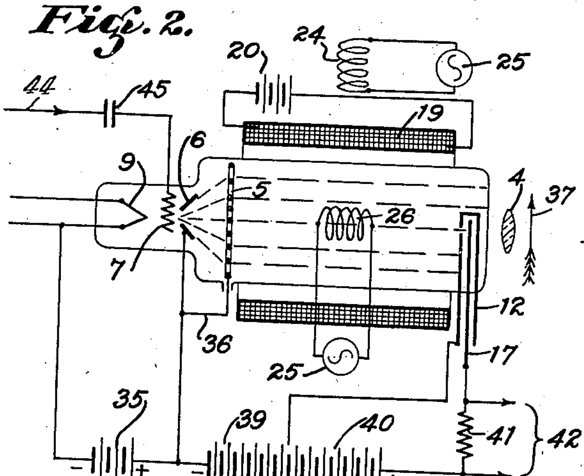


Fig. 3.

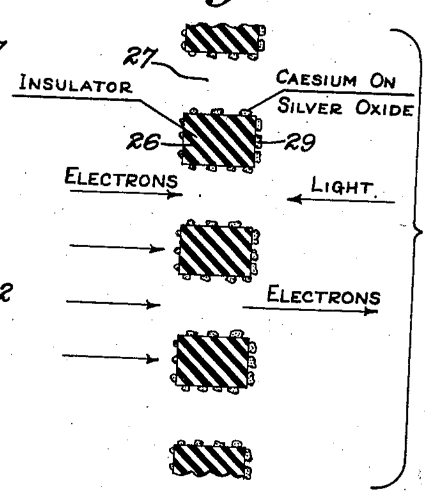
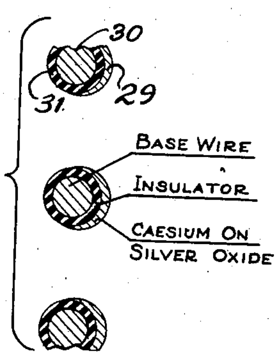


Fig. 4.



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Filed July 15, 1935 3 Sheets-Sheet 2

Fig. 5.

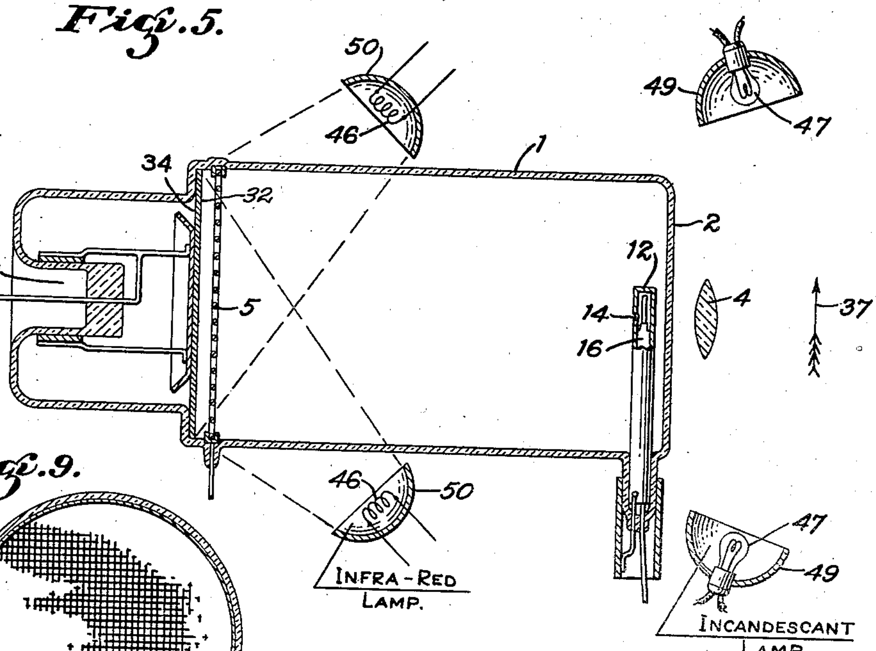


Fig. 9.

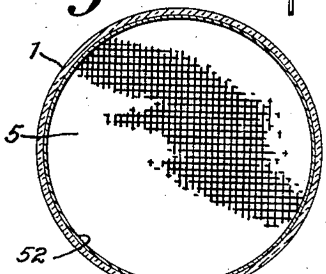


Fig. 8.

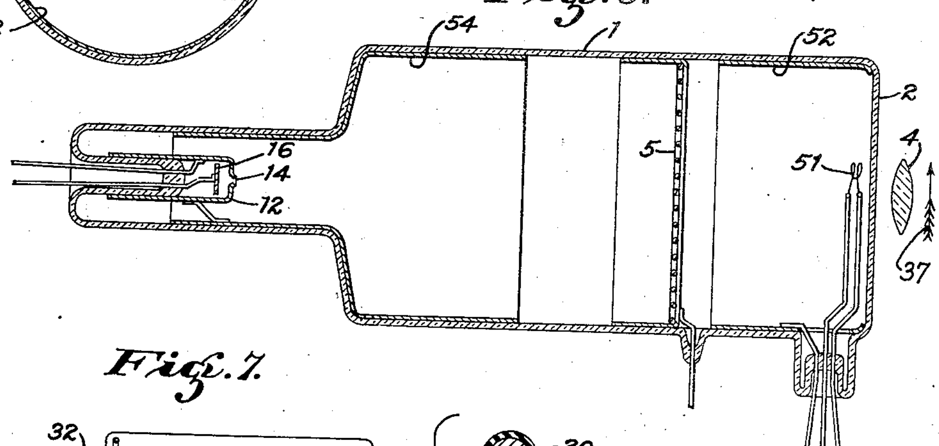
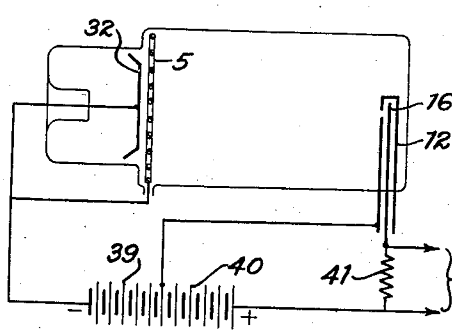


Fig. 7.



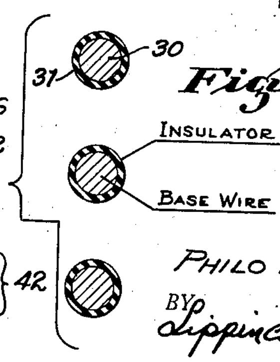


Fig. 6.

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Fig. 10.

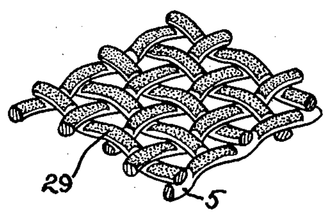


Fig. 11.

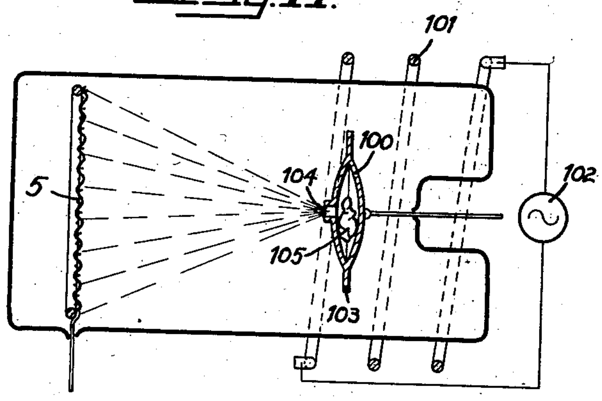


Fig. 12.

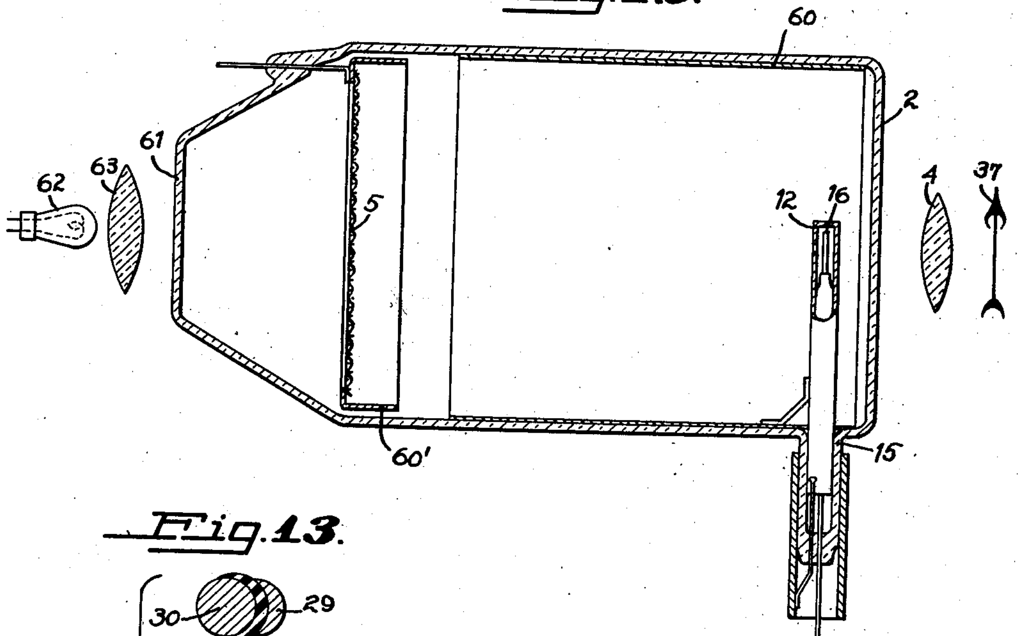
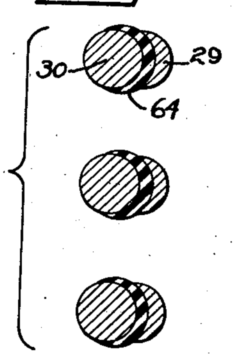


Fig. 13.



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Patented May 24, 1938

2,118,186

UNITED STATES PATENT OFFICE

2,118,186

IMAGE RECEIVING TUBE

Philo T. Farnsworth, San Francisco, Calif., assignor to Farnsworth Television Incorporated, San Francisco, Calif., a corporation of California

Application July 15, 1935, Serial No. 31,410

4 Claims. (Cl. 250—27.5)

My invention relates to a thermionic device, and more particularly to a cathode ray tube adapted to produce an electron image of greater intensity than can be ordinarily produced directly by the impact of an optical image upon a photoelectric surface.

The present application is a continuation in part of my invention disclosed and claimed as to system and method in my application, Serial No. 29,242 filed July 1, 1935 for an Electron image amplifier, this application dealing solely with tube structure.

Among the objects of my invention are: To provide a photoelectric tube having a high output; to provide a photoelectric tube which when energized will produce an output current greater than can be produced by the impact of light upon the photoelectric surface alone; to provide an image amplifying tube having an effective photoelectric emitter of greater sensitivity than has hitherto been produced; and to provide a simple and efficient electron image amplifying tube particularly suitable for use in television systems for the creation of a train of television signals.

Other objects of my invention will be apparent or will be specifically pointed out in the description forming a part of this specification, but I do not limit myself to the embodiment of the invention herein described, as various forms may be adopted within the scope of the claims.

In my prior application above referred to, I have described and claimed an embodiment of a method of electron image amplification employing the tube of the instant application. In previous applications and patents of mine I have described television transmitting apparatus and systems wherein an optical image of the object or picture field is thrown upon a photosensitive 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.

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

Describing my invention in broad terms, I prefer to utilize an envelope containing a source of electrons, these electrons being preferably low velocity electrons. In certain cases, I may use a thermionic emitter for this source but in other cases, I prefer to utilize a photoelectric surface and flood the surface with long wavelength light in order to obtain a stream of low velocity electrons therefrom. I then position in the path of this stream an apertured electrode or grid capable of having a charge fixed thereon in accordance with the spatial distribution of illumination intensities existing in an optical image.

At the other end of the tube, I prefer to position an apertured electrode, the aperture being of elemental area and positioned to allow electrons to pass therethrough and I place, immediately behind the aperture, a collecting anode to intercept electrons passing through the aperture. The tube when energized is supplied with moving magnetic fields which scan the electron image past the aperture so that successive elementary areas thereof may be collected to produce a train of television signals.

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 showing in Figure 5.

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

Figure 8 is a longitudinal sectional view of another embodiment of my invention.

Figure 9 is a cross sectional view which is identical with cross sectional views of the device shown in Figures 1, 5 and 8, looking toward the charge storage electrode.

Figure 10 is a perspective view of a mesh mosaic.

Figure 11 is a diagrammatic view of apparatus used in forming a silver mosaic.

Figure 12 is a longitudinal sectional view of another modification of my invention.

Figure 13 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 and 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 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 deposited thereon, leaving 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 the mosaic 29 of caesium on silver oxide is formed, as described before. 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, as will be later described.

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 11 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 100, a convenient means being the application of eddy currents from a coil 101 energized by an oscillator 102 to a container 103 having an aperture 104 facing the grid and enclosing silver metal 105. 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 10 in perspective and in Figure 13 in cross section.

In practice, a completely opaque film of silver has been evaporated onto a grid member, and the resistance between two contacts 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 creates 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 the gun grid 7 supplied with a radio frequency modulation voltage through input lead 44 and blocking condenser 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 8. 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 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 4. This is accomplished in practice by the use of reflectors 49 on the white lights and as it is also desirable that no red light illuminate object 37 reflectors 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 low 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 wavelengths 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 component 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-quarters 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 the embodiment shown in Figure 8, the source of the uniform electron stream is a filament 51 and the filament is surrounded by a cylindrical electrode 52 which tends to form a uni-potential space around the cathode emitter so that the electrons will be uniformly accelerated toward the grid 5, in this case provided with a photoelectric mosaic and formed as shown in Figures 3 and 4 or other charge storage electrodes such as are described and claimed in a companion application, Serial No. 30,118, filed July 6, 1935 for a Charge storage dissector.

In Figure 8, the end wall 2 is left free from any film so that the optical image is projected through onto the charge storage electrode 5, the filament assembly being so small that no appreciable amount of light is intercepted thereby. Electrons from the filament charge the mosaic surface 29 a uniform potential and the emission of electrons from the mosaic surface due to the light from the optical image falling thereon causes the formation of a charge image. This charge image modulates the electrons from the filament which are being drawn through the apertures in the charge storage electrode 5, and the modulated stream is then accelerated toward the anode aperture 14 selected areas thereof passing through to be collected by the collecting plate 16.

The space between the charge storage electrode or grid 5 and the collecting anode is partially surrounded by a film 54 on the inside of the envelope which acts as an electrostatic focusing aid and which is usually maintained at the potential of the anode. It will be seen that the structure involved in this particular embodiment is almost identical with that shown in Figures 1 and 5 with the exception that all the electrons travel in the same direction instead of reversing their directions as in the other embodiments.

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