Dec. 20, 1938. P. T. FARNSWORTH 2,140,695

CHARGE STORAGE DISSECTOR

Filed July 6, 1935

Fig. 1.

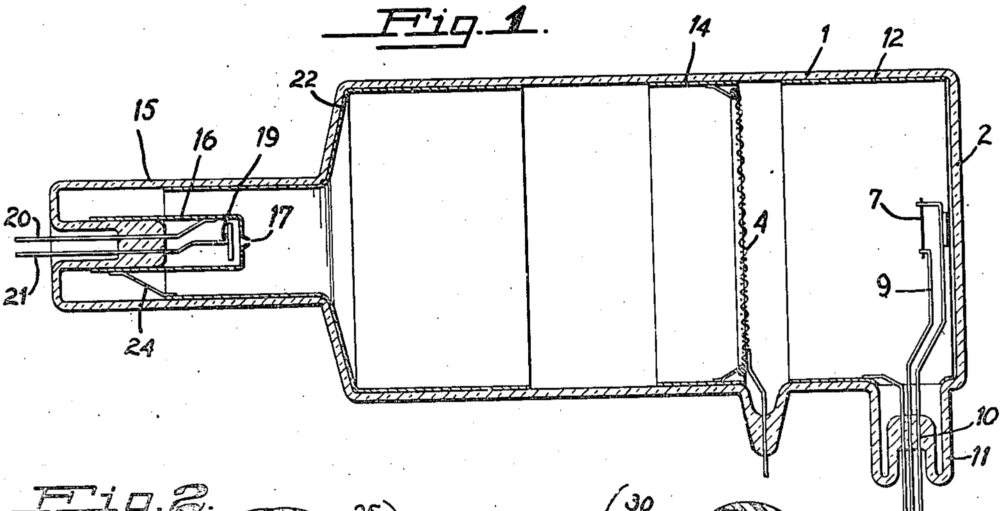
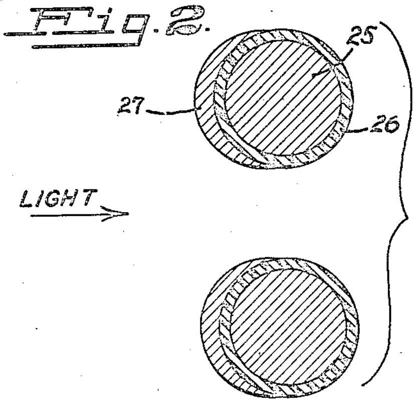


Fig. 2.



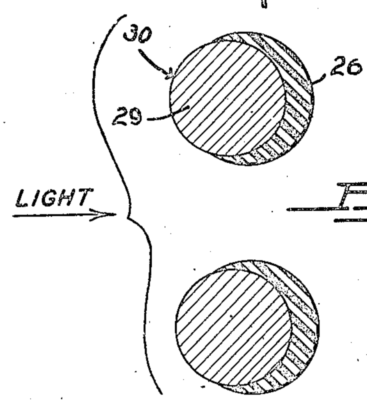
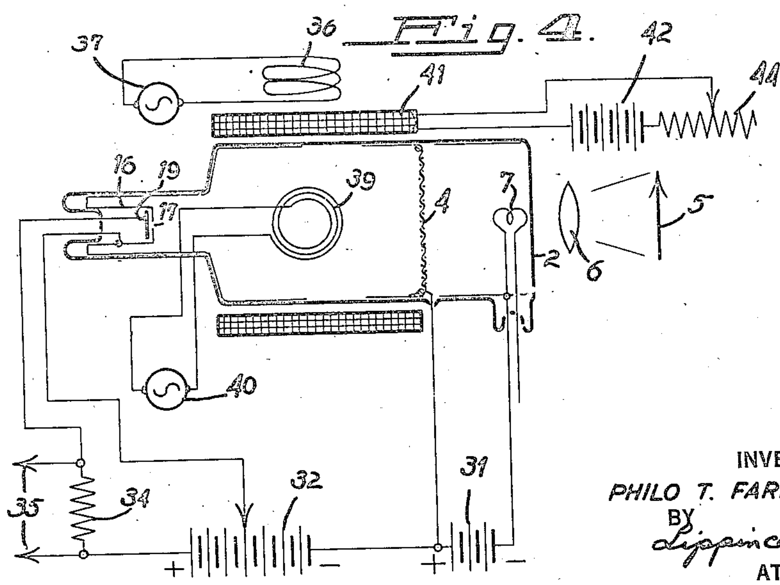


Fig. 3.

Fig. 4.



INVENTOR,
PHILO T. FARNSWORTH.
BY Lippincott & Metcalf
ATTORNEY

UNITED STATES PATENT OFFICE

2,140,695

CHARGE STORAGE DISSECTOR

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

Application July 6, 1935, Serial No. 30,118

4 Claims. (Cl. 178—7.2)

My invention relates to a charge storage dissector and more particularly to a photoelectric tube and system adapted for electron beam analysis for use in television or in other systems wherein electron beam analysis is desired.

This application embodies the broad method disclosed and claimed by me in application, Serial No. 29,242, filed July 1, 1935, for an Electron image amplifier, and this application describes and claims the means and method by which the tube structure shown in Figure 8 of my companion application, Serial No. 31,410, filed July 15, 1935, for Image amplifying tube is operated.

The broad method is applicable to both transmission and receiving cathode ray tubes and systems employing them, the specific embodiment described herein as utilizing my broad method being a transmission device.

Among the objects of my invention are: To provide a method of electron image amplification adapted for use in a transmitting dissector tube or in a cathode ray receiving tube; to provide a method of increasing the sensitivity of television transmission cells; to permit the production of television signals 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; to provide a means and method for modulating a uniform electron stream by photoelectrons created by an optical image; and to provide a means and method of discharging fixed charges.

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 United States Letters Patent, as follows: Patents Nos. 1,773,980, Aug. 26, 1930; 1,844,949, Feb. 16, 1932; 1,941,344, Dec. 26, 1933; Serial No. 668,066, filed 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 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 dissection 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 transmission 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 may 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 devices because of the fact that space charges are formed, the electrons in the space charge being released by the action of 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.

In the broadest aspect of the method disclosed herein, I form a charge image representing part or all of an optical image on an insulating surface and then utilize the charge image produced to modulate a uniform electron flow to form an electron image in accordance with the charge image, this being the broad method used in all of the apparatus of associated applications.

In the specific embodiment of my method presented here, I prefer to form a charge image on an insulating medium and then pass a stream of electrons having uniform cross sectional density through the charge image to produce an electron image corresponding to the charge image and to the optical image responsible for the charge image. The charge image releases electrons from a space charge in the uniform stream to form the electron image which is thus greatly more powerful than any image that could be created electrically by the direct action of light on photoelectric means.

Describing my invention broadly in terms of apparatus, I prefer to utilize a source of electrons preferably a filament mounted in an enclosing envelope and so positioned as to create an electron stream which is directed through a charge storage electrode on the way to a collecting anode. I prefer to form the collecting anode in the form of an apertured electrode having a collecting electrode in back of the aperture so positioned that the electron image formed by the action of the charge image on the uniform electron stream may be scanned past the aperture to produce an analysis of the electron image, thereby creating a train of television signals upon the collecting electrode.

The present invention differs from my own previously described devices of the same general type in that in the instant embodiment the charge storage electrode serves both as a source of photoelectrons for charging an insulating surface and also embodies the insulating surface itself; the photoelectric material being preferably on one side of the electrode and the insulating material on which the charges are fixed being preferably on the opposite side of the electrode.

In my previous embodiments above referred to I have either projected an electron image onto an insulating surface to project an image or I have provided the charge storage electrode with a photoelectric mosaic having discrete islands which may be charged by the photoelectric emission therefrom in accordance with the light intensities falling upon them. Inasmuch as the formation of a photoelectric mosaic is a difficult procedure and one which is liable to many accidents during the course of formation and would for that reason be hard to duplicate in commercial quantities for practical use, I have developed the type of charge storage electrode with which this particular case is concerned so that a charge image may be produced without the use of a photoelectric mosaic and yet the charge storage electrode as a whole will have the same action as if a mosaic were present. In other words, the charge storage electrode in this particular embodiment combines the insulating surface upon which charges are fixed and the photoelectric surface from which the energy comes to form the charges. I also prefer to operate the device so that equilibrium is accomplished independently of insulation leakage.

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 drawing, of which

Figure 1 is a longitudinal sectional view of a television dissector tube embodying my invention and provided with charge storage electrodes formed as indicated in

Figures 2 and 3, which are enlarged cross sectional views of the individual wires of two preferred forms of charge storage structures.

Figure 4 is a conventionalized diagram showing how the tube of Figure 1 may be connected for operation.

Describing the apparatus in detail, envelope 1 is provided at one end with a transparent window 2 through which an optical image may be projected onto a charge storage electrode or grid 4. The object is represented by an arrow 5 in Figure 4 and focused on a grid or charge storage electrode 4 by a lens 6. Adjacent the transparent window 2 I prefer to mount a source of flooding electrons 7 preferably in the form of a hot cathode either directly or indirectly heated. I prefer, however, to utilize a single filament with the leads 9 supporting the filament placed one back of the other and passing through a stem 10 in a small side arm 11. In this manner, the entire cathode structure obstructs very little light and therefore interferes inappreciably with the optical image passing it. If desired, an accelerating anode may be utilized in combination with cathode 7. I also prefer to surround the filament with an annular film 12 surrounding the cathode, this film being energized in any suitable manner to electrostatically control the paths of the electrons. For the same reason, I prefer to surround the charge storage electrode 4 with a grid band 14 preferably fixed to the wall of the tube and connected to the grid foundation wires.

The opposite end of the tube is provided with an axial extension 15 in which is mounted an anode assembly comprising an anode tube 16 provided with an aperture 17 facing the filament 7 and the charge storage electrode 4 and also provided with an interior collecting electrode 19 positioned immediately back of the aperture. The anode tube 16 is provided with an external lead 20 and the collecting electrode 19 is provided with an external connection 21. I also prefer to surround the anode end of the tube with an anode film 22 connected by means of link 25 with the anode sleeve. The combined action of the films 12–14–22 creates an electrostatic lens as described and claimed in my prior application, Serial No. 56,976, filed Dec. 31, 1935.

Among others, there are two structural embodiments which may be used in the grid or charge storage electrode 4, both of which, however, accomplish the same function. Figure 2 shows one way in which the grid structure may be made. Here a foundation wire 25 is provided with a uniform coating of insulating material 26 over the complete surface thereof and the insulating material on the side of the grid structure facing the window 2 is provided with a layer of photoelectric material 27. In the other embodiment, shown in Figure 3, the foundation wire itself is preferably of silver 29 having a sensitized photoelectric surface 30 thereon and the side of the charge storage electrode away from the window 2 is provided with a coating of insulating material 26. Thus, either modification will have a photoelectric surface facing the window 2 and an insulating surface facing the anode aperture 17.

In forming the charge storage electrode shown in Figure 2, I prefer to utilize nickel wire screen for the foundation 25 and form the insulating layer 26 thereon by completely smoking the grid with the fumes of burning magnesium to deposit a continuous layer of magnesium oxide. I then evaporate onto one side of the electrode a thin layer of metallic silver. This deposition may be accomplished by evaporation in vacuo as is well known in the art.

Oxidation of the silver film is then carried out preferably by using a high voltage glow discharge in oxygen and the oxidized surface is then sensitized with caesium, preferably with care being taken not to leave an excess of caesium. An excess of caesium can be prevented by baking the tube at sixty degrees on the pump after the photoelectric surface is formed, or by other means well known in the art; thus leaving a sensitive photoelectric surface facing the window 2, but a surface which is continuously conductive and not a mosaic.

In the second method of forming the charge storage electrode, the foundation screen of the electrode is preferably of solid silver, in other words, the screen is woven of silver wire. The screen is then smoked on one side only with magnesium oxide until it can be seen by examination that the silver wires on the side of the screen facing anode 17 are fully covered with magnesium oxide with bare silver wire facing the window 2. The screen is then subjected to the glow discharge in oxygen, the exposed silver portion oxidized, and caesium deposited on this oxidized surface so that a continuously conductive photoelectric surface is formed facing the window 2. Thus, it will be seen that in both embodiments a charge storage electrode is formed with a photoelectric surface facing the clear window in a position to receive an optical image thereon, whereas the opposite face of the screen directed toward the anode 17 is provided with an insulating surface.

In operation, the tube is hooked up in one preferred circuit as shown in Figure 4. Here the cathode is energized in any convenient manner and the charge storage electrode 4 is maintained at a potential positive to the filament 7 by means of a grid source 31. The anode tube 16 and the film 22 connected thereto are maintained at a positive potential to grid 4 by means of anode source 32 and the collecting electrode 19 is maintained still more positive from the same source 32 and is connected in series with an output resistor 34 across which output leads are connected to tube 16. The television signal appears in the output leads, and is a measure of the difference between the electrons collected by the tube and those passing through the aperture to be collected by electrode 19.

The tube is provided with preferably magnetic deflecting means moving the beam in two directions, coil 36 supplied by its oscillator 37 deflecting the image in one direction and coil 39, supplied by its oscillator 40 deflecting the image in a direction preferably at right angles thereto, thus causing scansion of the electron stream between the grid 4 and the aperture 17 in two directions across the aperture.

In order that the electrons passing through the charge storage electrode 4 be maintained in their electrical image relationship, I prefer to place around the path of the electrons a focusing coil 41 supplied with current by focusing source 42 under the control of a variable resistor 44 to focus the electron image in the plane of the anode aperture. The device is now ready for operation.

The object 5 is illuminated and the light reflected therefrom is focused by means of the lens system 6 onto the charge storage electrode 4. Inasmuch as the surface of the charge storage electrode 4 facing the object is photoelectric, photoelectric emission over the entire photoelectric surface will occur in accordance with the illumination of the elementary areas thereof.

I offer the following explanation of operation as based on observed results, the experimentation being by no means complete, as the obscurity and complexity of the problem renders my theory liable to reformation in view of additional facts when obtained. Therefore, I do not wish to be bound by all points of my present explanation although I believe it to be substantially correct.

During operation, I prefer to operate the charge storage electrode at a positive potential. Let us assume for a specific example a forty to fifty volt positive bias. Electrons from the flooding source 7 strike the photoelectric layer with a primary velocity spectrum of from zero to fifty volts. Secondaries are therefore emitted; most of them; however, having a small velocity, say, under .5 volts, but a small percentage will have a fairly high velocity even up to fifty volts, creating a secondary electron velocity spectrum.

The secondary electrons are drawn through the meshes of the grid and some of them strike the insulating surface thereof charging it negatively to a potential which may be assumed to be from .5 to 1.0 volts. If the average velocities of the secondaries which are emitted from the photoelectric surface from impact by flooding electrons is increased by increasing the voltage on the electrode 4, a point will be reached where the negative potential bound on the insulator is so great that the photoelectrons emitted by virtue of the light falling on the photoelectric surface are ineffective to change the potential on the insulating surface since they will not have enough velocity to strike the insulator.

The current flowing through the grid to the anode assembly then assumes a minimum value. When, however, the voltage on the grid is increased to a point where the anode current only approaches this minimum, the recovery after exposure of the photoelectric surface to light is very slow and may take several seconds. This behavior strongly indicates that the discharge of the charges bound on the insulating surface of the grid is due to electrons from the source 7 rather than from any leakage through the insulation to the foundation wire.

When the insulating surface is negative nearly all the flooding electrons from the cathode 7 which strike the grid structure will strike the conducting front surface. Those high velocity electrons which do not strike the front surface will have no tendency to strike the insulating surface unless a portion of the insulating surface is directly in their path. The number, therefore striking the insulator will be quite small. Those which do strike, however, will cause emission of secondaries from the insulating surface at a ratio greater than unity and will therefore discharge the insulating surface and create an equilibrium charge thereon independent of leakage.

The rate, however, at which the insulator is discharged will be dependent upon the amount of such primaries striking the insulating surface and the rate of discharge will be much slower. When the insulating surface is made negative by photoelectrons from the photoelectric surface, emitted under the influence of the optical image, the rate will also be proportional to the strength of the flooding beam from cathode 7. As the rate will vary spatially in accordance with the photoelectric emission, an electron image is formed in the stream passing through the grid to the anode assembly.

Inasmuch as it is very difficult to control the exact resistivity of the insulating material which is placed on the back of the grid, it is much more satisfactory to operate the tube in a manner such as has been above described where the grid is at a positive potential and where the high velocity electrons from the flooding cathode 7 control the rate of discharge, rather than having to depend upon the more uncertain leakage. It is, therefore, a great benefit in the operation of the device to utilize a flooding cathode and associated electrode structure which will give a beam of flooding electrons having a maximum density of electrons within a relatively low velocity category and a relatively smaller number of electrons within higher velocity categories. Thus, the large mass of low velocity electrons can be utilized to form the space charge in front of the grid and the high velocity category can be utilized partly to create secondaries by impact with the photoelectric surface, which pass through the grid meshes to strike the insulator, thus giving it a negative charge, and partly to pass through the grid meshes to impact the insulating material to eject secondaries therefrom thereby leaving a postive charge upon the insulator, the combination of the two charges creating a uniform equilibrium charge which is a function of the voltage between the grid and cathode.

Light falling on the photoelectric surface creates electrons which add to the equilibrium charge in greater or less degree in accordance with the illumination in the optical image thus creating an electron image back of the grid, the stream then being scanned to produce an amplified signal train.

It is only then necessary to so adjust the grid voltage so that at the maximum negative potential occurring on the insulating material, sufficient high velocity electrons will penetrate the grid meshes, impact the insulator and eject secondaries therefrom, to return the insulator to equilibrium at that point within the time allowed for optical image shift to the next picture field.

It is, however, possible to operate the device with the grid foundation at a potential less than the point of unity secondary emission ratio for the insulator, by accelerating the flooding electrons by an auxiliary flooding anode until they enter deeply into the meshes of the grid. Under these circumstances, it may be desirable to control the equilibrium charge by means of the leakage constant of the insulator or to utilize gas in the tube to affect charge leakage. In any event, the charge image is formed by the passage of photoelectrons from the photoelectric surface to the insulating surface, the only difference in operation being the manner in which the insulating surface is discharged.

In the tube of the present invention I have obtained all the desirable features of a photoelectric mosaic without the necessity of using a mosaic, and a tube having a large amplified output available as a signal current.

I claim:

1. The method of amplification comprising creating a steady electron emission from a relatively small source, applying a diverging field to said electrons to create a stream of picture area cross section, directing said electrons after divergence against an electron permeable photoelectric surface at a velocity sufficient to create secondary electrons, directly utilizing a portion of said secondary electrons to create an equilibrium charge pattern immediately adjacent said surface, projecting an optical image on said surface to create emission of photoelectrons therefrom, drawing both photoelectrons and secondary electrons in electron image relationship through said equilibrium pattern, and scanning the resultant electron image to produce a train of signals.

2. The method of amplification which comprises bombarding a photoelectric surface of picture area to produce a uniform emission of secondary electrons therefrom, simultaneously projecting an optical image on the same photoelectric surface to produce photoelectrons therefrom, combining the secondary electrons and the photoelectrons to produce a stream having an electron image cross section, spatially trapping a portion of said stream to produce a charge image registering with said electron image, modifying the entire stream by said charge image, and scanning the remainder of said stream to produce a train of signals.

3. Means for producing television signals, comprising a cathode ray tube having an envelope having a light conductive window at one end thereof, a thermionic cathode of relatively small size adjacent said window, an anode at the other end of said envelope, and a shield adjacent said anode and having an aperture of elemental dimensions therein exposing a portion of said anode to said cathode, an electron permeable conductive grid between said cathode and anode, said grid having a coating of photoelectric and secondary emissive material facing said cathode and a coating of insulating material facing said aperture, means for maintaining electrons in electron image relationship between said grid and aperture only, and means for scanning the electron image across said aperture to produce a train of television signals.

4. Apparatus in accordance with claim 3, wherein means are provided to cause electrons from said source to impact said photoelectric and secondary emissive surface with a velocity sufficient to create secondary electrons.

PHILO T. FARNSWORTH.