

Nov. 30, 1937.

P. T. FARNSWORTH

2,100,841

IMAGE ANALYSIS TUBE

Filed Sept. 7, 1935

Fig. 1.

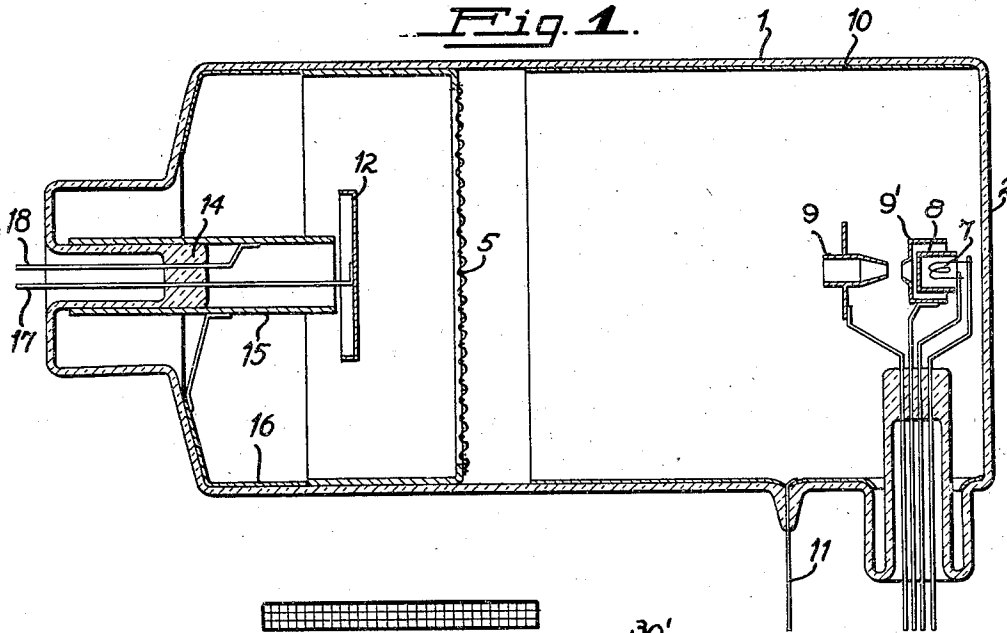


Fig. 2

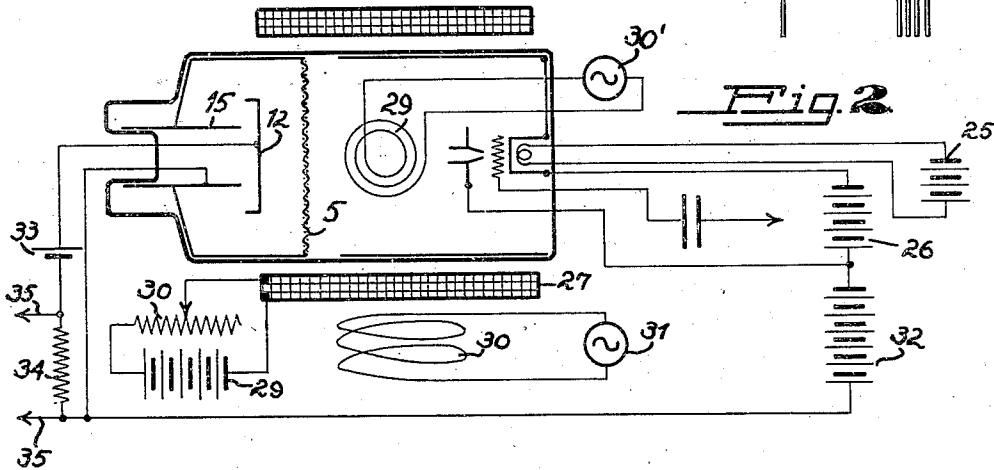
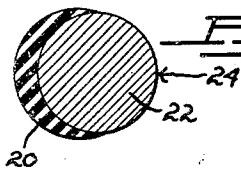
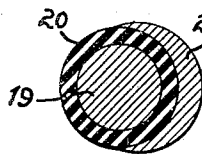


Fig. 4.

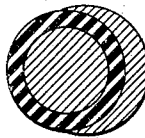
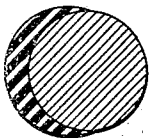


← LIGHT

Fig. 3.



← LIGHT



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UNITED STATES PATENT OFFICE

2,100,841

IMAGE ANALYSIS TUBE

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Application September 7, 1935, Serial No. 39,605

3 Claims. (Cl. 250—27.5)

My invention relates to a cathode ray dissector tube, and more particularly to a tube structure wherein image analysis may be carried out, primarily for the purpose of the production of a train of television signals or for other oscillographic uses.

This application is a companion application to application, Serial No. 30,119 filed July 6, 1935 for a Means and method of image analysis, filed contemporaneously with the present case, and I describe and claim herein the tube structure described but not claimed in the above application.

Among the objects of my invention are: to provide a cathode ray tube of high sensitivity for television transmission or general oscillographic use; to provide a cathode ray tube capable, when energized, of use when illuminated by reflected light of ordinary intensity; to provide a dissector tube having an output greater than that obtained from the usual type of photoelectric dissectors; to provide a television dissector tube which will have an output when energized of sufficient power to greatly reduce subsequent amplification; to provide a photoelectric scanning tube having a charge storage electrode therein; to provide a photoelectric cell whereby relatively large currents may be obtained in the dissection of an image; to provide an amplifying means which can be applied to an oscillograph tube; to provide an amplifying tube for photoelectric currents whereby extremely high amplifications may be obtained within the tube itself; to provide a means for charging an insulated surface; to provide a cathode ray tube having the full equivalent therein of a photoelectric mosaic without any actual mosaic structure; to provide a means for fixing charges on an insulator; and to provide a simple and efficient cathode ray dissector tube.

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 previous patents and application for United States Letters Patent, as follows: Patent No. 1,773,980 issued Aug. 26, 1930, Patent No. 1,844,949, issued Feb. 16, 1932, and Patent No. 1,941,344, issued Dec. 26, 1933, and 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 means 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 principles of my prior inventions are retained and other desirable features added. In my prior application for a Charge storage dissector, mentioned above, I utilize a specific embodiment of my broad method by forming a charge image on an insulating medium and then passing 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. In that prior application the charge image released electrons from a space charge in the uniform stream to form the elec-

tron image, which thus became more powerful than any image which could be created electrically by direct action of light or photoelectric means. The present application differs from the prior application referred to in that the electron image is not scanned in the present application.

The broad method described and claimed in my application for an Electron image amplifier, supra, is that of forming a charge image in space and passing a uniform electron stream through this charge image to create an electron image which is then scanned to produce a train of television signals.

The broad method of the present case utilizes the same broad principles as outlined above, but modified in that I form a charge image in space corresponding to an optical image as far as spatial distribution is concerned, and then pass a defined beam of electrons through elementary areas of the charge image to produce modification of the electron beam, this modification then being collected to form the train of television signals. In other words, the charge image is scanned by a moving beam of electrons, and the amount of modification by the charge image of this beam is the television signal.

Broadly, in terms of apparatus, my present invention comprises the use of means for forming a charge image bound on an insulator, this image being formed by the action of an optical image on a photoelectric surface closely adjacent thereto. The charge image is then scanned by an electron beam emitted from an electron gun in two directions so that successive elementary areas of the insulating surface carrying the charges influence the electron beam and modify it. The electrons remaining in the beam after modification are collected upon an anode and utilized in an output circuit to form the train of television signals desired.

The means by which the charge image is formed in this particular invention is the same as that described in my copending application, Serial No. 39,604 filed September 7, 1935, for a Charge storage dissector tube, and the method by which the charge image is formed is fully described and claimed in my application for a Charge storage dissector, mentioned above. In these two applications 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 are preferably on the opposite side of the electrode.

I am fully aware that devices operating somewhat along the lines of the device herein to be described have been utilized before, but these prior devices have all utilized a mosaic photoelectron surface comprising a multitude of discrete islands of photoelectric material. Inasmuch as the formation of such 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 utilized in this particular instance 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 the 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, and this particular photoelectric surface may be, under the teachings of my various inventions referred to, continuously conductive.

Various other modifications and applications of my invention will be apparent to those skilled in the art, and for other broad objects of my invention I prefer to refer to a detailed description of a preferred embodiment of my invention as shown in the drawing of which:

Figure 1 is a longitudinal sectional view of a preferred type of dissector tube embodying my invention and provided with charge storage electrodes formed as indicated in Figures 3 and 4.

Figure 2 is a conventionalized diagram showing one circuit in which the tube of Figure 1 may be connected for operation.

Figure 3 and Figure 4 are cross sectional views, greatly enlarged, of the individual wires of two forms of charge storage structures.

Describing my apparatus in detail, an envelope 1 is provided at one end with a transparent window 2 through which an optical image of an object may be projected upon a charge storage electrode 5 by means of any convenient lens system.

An electron gun assembly is provided closely adjacent the window 2. This gun assembly comprises a heater 7 and emitter 8 and an apertured anode 9, the assembly being cooperative to project a narrow defined beam of electrons on the charge storage electrode 5. In practice the gun assembly is made sufficiently small so that it does not obstruct an appreciable amount of light, nor does it distort the optical image to any great degree. I also may provide a control grid 9' in case it is desired to modulate the scanning beam, and therefore the tube output at radio frequency, for example.

A cathode film 10 is provided on the side walls of the envelope 1, and has an exterior connection 11, and a collecting anode 12 is positioned on the side of the charge storage electrode 5 opposite the gun. This collecting anode 12 is mounted on a stem 14 which also supports an anode lead shield 15 to which is attached a charge storage film 16 extending along the walls of the tube and connecting to the edges of the charge storage electrode 5. Exterior connection 17 is provided for the collecting anode, and an anode shield connection 18 is provided for the anode shield. The combined action of the films 16 and 10 creates an electrostatic lens, as described and claimed in my prior application, Serial No. 56,976 filed December 31, 1935.

Among others, there are two structural embodiments which may be used in the charge storage electrode 5, both of which, however, accomplish the same function. Figure 3 shows one way in which the grid structure may be made. Here, a foundation wire 19 is provided with a uniform coating of insulating material 20 over the complete surface thereof, and the insulating material on the side of the structure facing the window 2 is provided with a layer of photoelectric material 21.

In the other embodiment shown in Figure 4, the foundation wire itself is preferably of silver 22 having a sensitized photoelectric surface 24 thereon, and the side of the charge storage electrode away from the window 2 is provided with a coating of insulating material 20. Thus, either modification will have a photoelectric surface

facing the window 2 and an insulating surface facing the collecting anode 12.

In forming the charge storage electrode shown in Figure 3, I prefer to utilize a nickel wire screen for the foundation wire 19 and form the insulating layer 20 thereon by completely smoking the screen with the fumes of burning magnesium to deposit a continuous layer of magnesium oxide. I then evaporate on this 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. Oxidization of the silver film is then carried out 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 the collecting anode 12 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 12 is provided with an insulating surface.

In operation the tube is hooked up in one preferred circuit as shown in Figure 2. Here the heater 7 is energized by heater source 25 heating the cathode 8, the front face of which faces the anode opening and is preferably coated with an electron emitting material. Electrons are thus emitted and the gun anode 9 is connected to the cathode through a gun source 26 with a positive potential on the anode so that an electron beam of relatively small cross section is projected into space in the direction of the charge storage electrode 5.

In order that the cross section of the beam contacting the charge storage electrode 5 be of elementary size I prefer to focus the electrons in the beam in the plane of the charge storage electrode 5, following the method disclosed and claimed in my Patent No. 1,986,330, patented January 1, 1935, utilizing for this purpose a focusing coil 27, the magnetic field thereof being produced by current from focusing source 29 under the control of a variable resistor 30.

I also prefer to be able to move the electron beam in two directions in order that the entire picture area of the charge storage electrode 5 be scanned in successive elementary areas thereof, and I utilize for that purpose preferably magnetic means comprising scanning coils 29 and 30 supplied with current from scanning oscillators 30' and 31, respectively.

The charge storage electrode, together with the collecting anode shield, is maintained at a potential somewhat positive to the electron gun by attachment to an accelerating source 32, and the collecting anode 12 is maintained still more positive by battery 33, the positive end of which is connected directly to the collecting anode 12 and the negative end to an output resistor 34 across which output leads 35 are connected.

The device is now ready for operation.

An object or picture field is illuminated, and the light therefrom is focused by means of a lens system onto the photoelectric face of the charge storage electrode 5. The photoelectric emission therefore will take place over the entire illuminated surface in accordance with the illumination intensity of the various 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 fundamentally correct.

During operation I prefer to operate the charge storage electrode at a positive potential. Let us assume, for a specific example, that the grid foundation is operated at a potential greater than the point of unitary secondary emission ratio for the insulator. Under these conditions the photoelectrons emitted from the front face of the charge storage electrode under the influence of light will be pulled through the grid meshes and some portion of them, at each elementary area, will be trapped on the insulator immediately behind the illuminated area, and thus a negative charge will be formed on the insulator which will represent in value the illumination intensity falling on the photoelectric surface emitting these electrons. Thus, there will be formed on the insulating surface facing the collecting anode 12 a charge image representing spatially the illumination intensity of the optical image. The charge storage electrode is then scanned by means of the beam from the gun under the control of the scanning oscillators and coils, and as it passes over the screen, certain of the electrons in the lower velocities in the scanning beam will tend to pass through the grid meshes to reach the collecting anode 12.

Certain of the electrons in the scanning beam, however, will have higher velocities than others, and certain of these electrons will strike portions of the insulating surface with a sufficient velocity to create secondaries, thus creating a positive charge thereon, the amount of which will be dependent upon the amount of negative charge already on that elementary area of the insulator and the number of such impacting electrons.

As the fixed charges vary in successive elementary areas in accordance with the optical image, the potential of the insulator at the point of scan will also vary, and more or less low velocity electrons from the beam will pass through the charge storage electrode meshes, as determined by the combined charges on the insulator. Those electrons which do pass through the screen are collected upon the collecting electrode 12 and passed as a current through the output resistor 34, thus giving rise to a train of television signals, the amplitude values of which will represent the optical illumination of the points under scan.

At the same time, the action of the high velocity component scanning beam, by producing secondaries, leaves a positive charge upon the insulator which tends to return to an equilibrium value due to the leakage through the insulator to the foundation. Equilibrium being accomplished, with the next optical shift there is a new charge built up on the insulator from the photoelectric emission which again modifies the beam on its next passage over that particular area.

The charge storage electrode 5 may also be operated in such a manner that no secondaries are produced by the action of the scanning beam, and in this case the modulation is downward, the scanning beam simply being modulated by the charges fixed on the insulator; and equilibrium is also obtained in this case by leakage which, of course, is to be regulated so that equilibrium is obtained between optical image shifts.

There will be other methods of operating the device apparent to those skilled in the art whereby combinations of charges, either positive or negative, in accordance with the velocity of photoelectrons and scanning electrons reaching the insulator, can be utilized to modulate the electron beam as it sweeps over the charge storage electrode.

My invention, as outlined in the instant case, utilizes therefore the cross section of the scanning beam as an effective scanning aperture and no apertured anode is needed, collecting anode 12 being positioned so that it will receive electrons passing through the screen at any elementary area of the screen. There is no question in the present instance of an electron image formed in space, as in the other embodiments referred to in my previous application listed above, although there is of course an electron image formed in the plane of the charge storage electrode while the photoelectrons are passing through the meshes of the electrode to charge the insulated surface.

I have therefore succeeded in forming a charge image on an insulating surface without the use of a photoelectric mosaic, and with very simple apparatus. Amplifications better than one thousand and have been obtained without the use of excessively high voltages or complicated apparatus, thus eliminating the use of high gain amplifiers with their accompanying noise factors.

I claim:

1. A cathode ray tube comprising an envelope containing an apertured control electrode having a photosensitive face and an opposite insulating face, a cathode and anode cooperating when energized to direct an electron beam of elemental cross section against said photoelectric face, and a collecting anode adjacent said insulating face.

2. A cathode ray tube comprising an envelope containing an apertured control electrode having a photosensitive face and an insulating face, a cathode and anode cooperating when energized to direct an electron beam of elemental cross section against said photoelectric face, a collecting anode adjacent said insulating face, a film on the wall of said envelope enclosing at least a greater portion of the path between said cooperating cathode and anode and said control electrode, and conductive means extending from the edges of said control electrode along the wall of said envelope substantially enclosing said collecting anode.

3. A cathode ray tube comprising an envelope having a transparent window and containing an apertured control electrode having a photosensitive face and an opposite insulating face, said photosensitive face presented to said window, a cathode and anode cooperating when energized to direct an electron beam of elemental cross section against said photoelectric face, and a collecting anode adjacent said insulating face.

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