Sept. 14, 1937. L. E. FLORY ET AL 2,093,166

ELECTRIC DISCHARGE DEVICE

Filed July 26, 1935 2 Sheets-Sheet 1

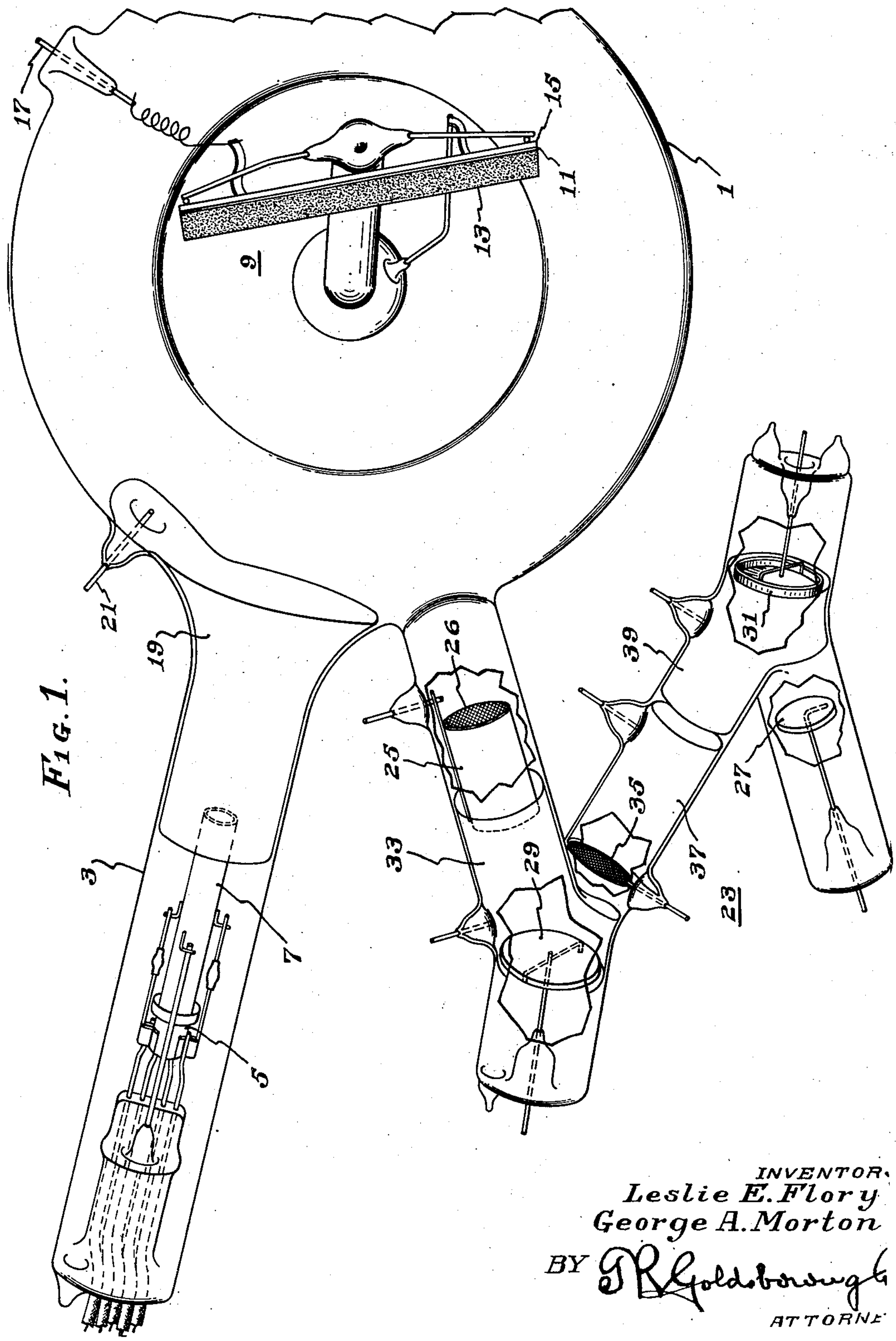

FIG. 1.

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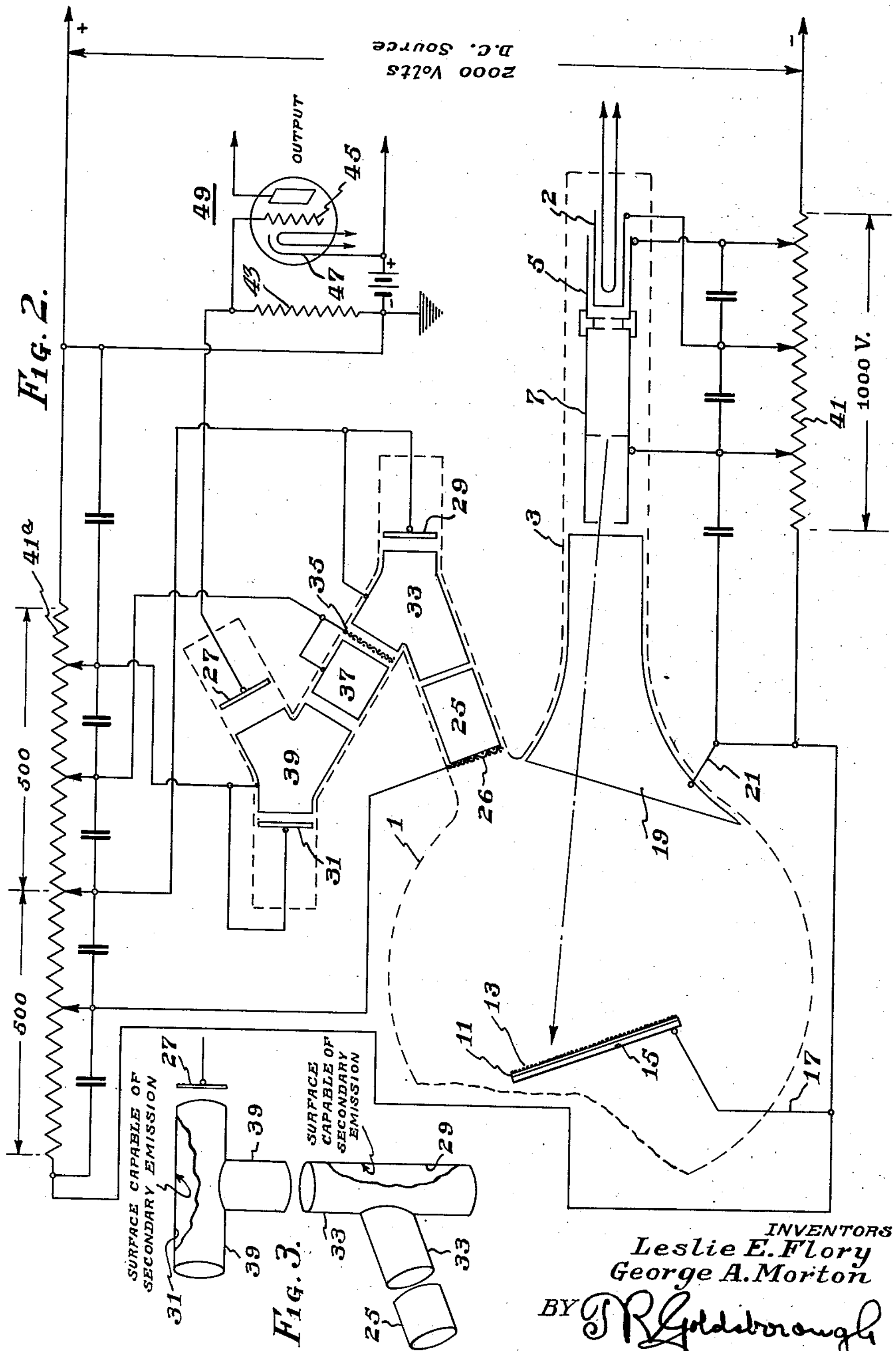

FIG. 2.

FIG. 3.

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Patented Sept. 14, 1937 2,093,166

UNITED STATES PATENT OFFICE

2,093,166

ELECTRIC DISCHARGE DEVICE

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Application July 26, 1935, Serial No. 33,330

8 Claims. (Cl. 250—27.5)

Our invention relates to electric discharge devices; more particularly to cathode ray tubes and methods for utilizing the same in television transmitters and the like.

A cathode ray tube of the general type to which our invention more especially relates (though not limited thereto) comprises a target element, constituted by a plurality of minute photo-sensitive particles insulatingly supported upon a metallic back-plate, on which target element an optical image of a scene to be transmitted is projected. In addition the tube includes an electron source and means are provided whereby a beam of electrons from the source may be caused to "scan" the photosensitive particles whereby, when the device is in operation, the sequential neutralization of the electrical charges acquired by the particles produces a train of electrical impulses in an output circuit connected to the back-plate, which impulses correspond in amplitude to the light intensity of the elemental areas of the optical image.

Heretofore it has been generally customary to connect an output impedance device, such as a resistor, directly to the back-plate which supports the photo-sensitive elements and to impress upon external amplifier stages the potentials appearing across the resistor. As will be apparent to those skilled in the art, such connections to subsequent amplifier stages unavoidably introduce stray capacities to ground which tend to attenuate the higher frequencies appearing across the output resistor and, consequently, militate against "definition" in the scene when received at a distant point either by radio or over a wire channel. Also, as is well known to those skilled in the art, amplifiers of the thermionic type which, heretofore, have been utilized in connection with cathode ray transmitting tubes are inherently noisy. That is to say, the output current from a multi-stage amplifier will contain spurious frequencies occasioned by shot effect, thermo agitation in the coupling devices, etc., and also by reason of other obscure causes.

It is, accordingly, an object of our invention to provide a combined cathode ray television transmitting tube and amplifier that shall be less noisy in operation than devices heretofore known.

Another object of our invention is to provide a combined television transmitting tube and amplifier that shall be more efficient than devices heretofore known, especially with respect to the amplification of currents at the higher frequencies generated during the scanning of an optical image.

Another object of our invention is to provide a combined cathode ray television transmitting tube and amplifier, the output current from which shall be substantially devoid of spurious signals that have no relation to the scene being televised when the system is in operation.

A still further object of our invention is to provide a method for electronically amplifying a train of electrical currents corresponding to an optical image.

The foregoing objects and other objects ancillary thereto we prefer to accomplish by combining a television transmitting tube of the type manufactured by RCA Manufacturing Company, Inc. under the trade-mark "Iconoscope", with an electron multiplier such, for example, as the device exemplified by the application in the name of George A. Morton et al., Serial No. 8630, filed February 28, 1935 and assigned to Radio Corporation of America. It is not to be inferred, however, that we are restricted to electron multipliers of the type disclosed in the Morton application since multipliers of other types may be utilized provided, of course, that such multipliers are so associated with the cathode ray tube that electrons released within the said tube may be drawn into the multiplier to therein give rise to secondary electrons which, in turn, are utilized for the production of further secondary electrons in as many electronic amplifying stages as may be necessary.

The novel features which we believe to be characteristic of our invention are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and method of operation will best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a view in perspective of a device constructed according to our invention, portions of the device being broken away to more clearly show the electrode structure,

Fig. 2 is a diagram exemplifying the connection of the various tube elements to potential sources during the operation of the device as a television transmitter, and

Fig. 3 is a view in perspective of several combined secondary emitters and electron-lens elements.

Referring now to Fig. 1 of the drawings, a cathode ray tube of the type to which our invention pertains is constituted by a bulbous evacuated container 1 having an elongated neck portion 3 wherein is mounted an electron source of the type commonly designated an "electron gun". The electron gun comprises a thermionic cathode 2 (not shown in Fig. 1 but exemplified in Fig. 2) surrounded by a grid element 5 coaxial therewith and includes a cylindrical first anode 7 coaxial with the grid element. The specific construction of the gun forms no part of our present invention and it is now so well known to those skilled in the art as to need no further explanation.

A cathode or target 9, of the mosaic type, is mounted in the bulbous portion of the container and is so oriented with respect to the electron gun as to be accessible to the electron stream, or cathode ray during the scanning operation. The target is constituted by a sheet of insulating material 11 such as mica, the surface of which, exposed to the electron stream, carries a large number of minute discrete photo-sensitive metallic particles 13. The mica sheet, in turn, is supported from a metallic back-plate 15 which is provided with a lead 17 that extends through a wall of the tube to the exterior thereof. In the drawing, which is a view of our improved device looking down into it from the top thereof, the target appears foreshortened; it is to be understood, of course, that in the actual device the target is substantially square or rectangular.

The inner surface of the neck portion of the container, adjacent to the end of the first anode, is provided with a metallic coating 19, to which is connected an exteriorly extending conductor 21. The coating has the double function of focusing the cathode ray to a fine spot upon the target and of accelerating photo and secondary electrons away from the photosensitive globules during the scanning operation. The metallic coating may also extend over the whole inner surface of the bulb, with the exception of an area sufficiently large to permit focusing of an optical image on the target. The more extensive coating, if utilized, prevents the walls of the tube from acquiring charges and gives rise to optimum field-conditions.

Attention is also directed to the fact that, in order to simplify the drawings, the ray deflecting coils, usually four in number, one pair for horizontal and one pair for vertical deflection, are omitted.

During the utilization of the device to transmit or televise a scene, an optical image of the scene is focused sharply upon the surface of the target carrying the photosensitive particles. The light causes emission from the particles of photo-electrons which are accelerated toward the conductive coating within the neck portion of the tube. It is our belief that, as a result of the emission of photo-electrons, each minute globule acquires a charge proportional to the light intensity of the elemental area of the optical image that is focused upon it. During the scanning operation, as each globule is struck by the beam, its charge is neutralized and, at the same time, secondary electrons are emitted from the globule, their number varying in proportion to the neutralized charge.

As hereinbefore pointed out, one of the objects of our invention is to make use of the secondary electrons rather than the changes in the electrical condition of the device occasioned by the successive neutralizing of the minute charges acquired by the particles. For this purpose we may connect to the container an electron multiplier of the electrostatic type disclosed in the aforementioned Morton et al. application in such manner that the vacuous spaces of the main cathode ray tube and of the multiplier are continuous. It is not to be inferred, however, that we are limited to multipliers of the electrostatic type. Any other multiplier may be utilized, such for example as one having focusing devices of the electromagnetic type. The latter we do not believe to be quite so good as those of the electrostatic type, since the focusing fields tend to interfere with the ray-deflection fields.

Substantially as disclosed in the Morton et al. application, an electron multiplier of the type that we may use is constituted by an N shape evacuated container 23 in one end of which is mounted a cylindrical accelerating electrode 25 and in the other end of which is mounted an output electrode 27. The end of the cylinder toward the cathode ray tube may be covered by a metallic screen 26 which somewhat improves the operation of the device. An electrode 29 capable of secondary emission is mounted within the N-shape container at the junction between the first leg thereof and the connecting portion between it and the second leg and a similar electrode 31 is mounted within the container at the junction between the connecting portion and the second leg. Each secondary electron emissive electrode, hereinafter referred to as a multiplying electrode, may be so disposed that the axes of the leg and connecting portion adjacent thereto make substantially equal angles therewith.

For the purpose of concentrating, accelerating and directing electrons which are drawn from the main container by the accelerating electrode 25, an electron lens is disposed between the said electrode and the first multiplying electrode 29. This lens is constituted by an electrostatic field which is set up between the end of the accelerating electrode cylinder and a metallic coating 33 upon the inner wall of the first leg of the container to which an appropriate positive potential may be applied as will hereinafter be explained more in detail.

For the purpose of removing secondary electrons from the first multiplying electrode 29 and of giving them an initial velocity toward the second multiplying electrode 31, we may interpose within the connecting member of the tube an accelerating screen element 35 to which a positive potential may be applied. In order that the secondary electrons from the first multiplying electrode may be further accelerated and concentrated upon the second multiplying electrode 31, we interpose a second electron lens, constituted by a plurality of spaced apart conductive wall coatings 37 and 39, between the first multiplying electrode and the second multiplying electrode. To these coatings the proper positive potentials may also be applied, as will later be shown.

The screen 35 is not an absolute essential of our improved device. If it is omitted, the first element 37 of the electron lens adjacent to the first multiplying electrode, if maintained at a sufficiently high positive potential with respect to the electrode 29, will serve to remove the secondary electrons therefrom and to direct them toward the next multiplying electrode.

If desirable, the second leg of the container may be replaced by a second connecting tube provided with an additional accelerating screen, analogous to the screen element 35, as well as suitable electron-lens-forming elements, and the secondary electrons from the second emitter 31 may again be concentrated and directed toward a third multiplying electrode. For the purpose of simplifying the drawings, however, we have omitted further multiplying electrodes and have merely shown the output electrode **27** as exposed to the secondary emitter **31**.

We wish it also to be clearly understood that the elements constituting the electron-lenses may be disposed exteriorly of the container without departing, in any way, from the spirit of our invention.

The accelerating cylinder **25** is made of nickel, which material may also be utilized for the accelerating screen electrode **35**. The multiplying electrodes or targets **29** and **31** are of pure silver, substantially one inch in diameter and ten-thousandths of an inch thick. To enhance secondary emission, the active surface of each multiplying electrode may be oxidized and caesiated, as explained in the Morton application. The output electrode **27** may be made of tantalum or an analogous metal, three-quarters of an inch in diameter and five-thousandths of an inch thick.

Having in mind that the aforementioned Morton application might go to patent before the issuance of our present application, it is thought best to make this disclosure complete by giving the sequence of operations involved in manufacturing the electron multiplier per se, as actually carried out in the laboratory of RCA Manufacturing Company, Inc., at Camden, New Jersey, U. S. A.

The glass envelope was first fabricated in the form shown, the ends of the legs and the junctions between the legs being left open in order to permit the sealing therein of the respective electrode-supporting presses.

After the glass blank was prepared, the positions of the metallic coatings on the glass were marked off and, on the inside of the blank, was deposited a commercially available platinizing solution following the marks previously made. The whole blank was then heated to approximately 400° centigrade in order to reduce this platinizing solution to metallic platinum. The electrodes, previously described, were mounted on the wires of the glass presses which were then sealed in place. The tube was sealed to a high vacuum system by means of a tubulation (not shown), through which the tube could be evacuated. An appendage (not shown) containing pellets of a caesium compound, such as caesium chromate, and a reducing agent, such as aluminum powder or silicon powder, was sealed onto the tube by means of another tubulation (not shown) through which the caesium from the pellets could be admitted to the main body of the tube.

The tube was then baked at 450° centigrade, being evacuated at the same time. The bake continued for approximately thirty minutes after the oven reached the final temperature. After the baking, the tube was cooled and a small amount of pure oxygen was introduced into it at a pressure of approximately 1 mm. of mercury. The cathode and multiplying electrodes were next oxidized by passing an electrical discharge from these elements to some other element in the tube until the electrode surfaces acquired a bluish-green tinge. The oxygen was then pumped out and the pellets of caesium compound and reducer were heated sufficiently to start the reaction which yields metallic caesium. The metallic caesium was driven, by means of heating the appendage, into the main body of the tube. The tube was once more baked at 200° centigrade for approximately ten minutes and allowed to cool. The caesium appendage was then sealed off the tube and the tube sealed off the vacuum system.

In the manufacture of the composite device shown in Fig. 1 it is, of course, to be understood that the multiplier is sealed to the cathode ray tube before the first mentioned evacuation step is initiated. Also, the subsequent steps of oxidizing and caesiating the electrodes of the multiplier and the surface of the target of the cathode ray tube are taken simultaneously.

It might be thought that the caesium would be deposited upon the lens-elements and the electrodes other than those which are intended for primary or secondary emission. Such is undoubtedly the case, but, by reason of the greater affinity of caesium for an oxide, particularly silver oxide, when the tube was heated in the final heating, most of the caesium was driven off of the other elements and was taken up by the oxidized silver electrodes. The caesium forms a chemical compound with the silver oxide which is reasonably stable, although the actual chemical reaction that takes place is not definitely and accurately known to us.

From the foregoing description of the device shown in Fig. 1 of the drawings, it is, of course, possible to infer that the zig-zag shape of the multiplier is necessary. Such is not the case, however, since the elements themselves may be arranged in a zig-zag path within a cylindrical container.

Referring now to Fig. 2 of the drawings, in the operation of our improved device it is preferable to so supply potentials to the various electrodes therein that a potential gradient exists between the output electrode of the multiplier and the electron emissive cathode of the cathode ray tube per se.

Such potentials may be supplied from any well regulated D. C. potential source, as exemplified in the drawings by a potential divider **41**—**41***a* to the negative end of which the grid or control element **5** of the cathode ray tube is connected and to the positive end of which the output electrode **27** of the multiplier is connected over a circuit including an impedance device **43** connected between the grid **45** and cathode **47** of an output amplifier tube **49**. From an inspection of Fig. 2, it will be noted that the cathode of the transmitting tube is variably connected to the potential source at a point more positive than the connection to the source of the grid or control element. Such variable connection is for the purpose of properly adjusting the static bias on the transmitting tube to the best operating point.

It is also to be understood that the various elements of the combined system may be connected, respectively, to points upon the potential source successively more positive than the connection thereto of the grid or control element in the cathode ray tube. As a matter of fact, however, we have found that the first electron lens element **33** and the first multiplying electrode **29** may be connected together, that the second lens element **37** and the screen **35** may receive the same potential and that the second multiplying electrode **31** and the third lens element **39** may also be maintained at the same positive potential. Further, the elements **29** and **33** and **31** and **39** mentioned, shown in Fig. 2 as being directly connected together outside of the device, may be physically continuous within the container. Such modification is exemplified by Fig. 3.

Omission of the element 37, in the modification, does not militate against the focusing action, since an electron lens is constituted by the cylinders 33 and 39. It is not to be inferred from the foregoing, nevertheless, that we are limited to either of the modes of connection described since many other possible connection systems may be utilized, having in mind the basic principle of the electron multiplier, namely, that primary and secondary electrons are to be progressively accelerated from the input thereto toward the final output electrode.

When an optical image is focused upon the layer of particles 13 in the transmitting tube each particle, according to our present understanding, emits photo-electrons which are drawn over toward the screen 26, thus causing the said particles to acquire charges, respectively, that are proportional to the light intensity of the elemental areas of the optical image. During the scanning operation, whereby a cathode ray or beam of electrons is caused to repeatedly traverse the photo-sensitized surface in two directions simultaneously, the charges are sequentially released, as heretofore mentioned, and at the same time secondary electrons are emitted in an amount varying in proportion to the neutralized charges. According to our present understanding of the manner in which our improved device functions, the secondary electrons are drawn over into the electron multiplier by reason of the fact that the accelerating cylinder 25 and the screen 26 are maintained at a potential which is high relative to the potential of the focusing elements 19. Once within the accelerating cylinder the electrons are subjected to the potential of the first multiplying electrode and are accelerated toward it. The cylinder and focusing element 33 together constitute an electron lens which focuses and directs electrons toward the first multiplying electrode 29. The secondary electrons emitted from the electrode 29 are given an initial acceleration toward the second multiplying electrode by means of the screen 35.

The electrons emitted by the first multiplying electrode are directed and focused upon the second multiplying electrode by means of an electron lens constituted by the coatings 37 and 39. Upon reaching the second multiplying electrode 31 the secondary electrons, in turn, drive out further secondary electrons which are drawn over to the output electrode and give rise to a fluctuating current in the output resistor that is a greatly amplified replica of the electron current which enters the multiplier from the transmitting tube.

Obviously, we may employ as many multiplying stages in the multiplier as are desirable without departing from the spirit of our invention. Furthermore, it is entirely feasible to connect a plurality of separate multipliers to the transmitting tube at different points and to combine the output currents therefrom in parallel in a single output resistor. When a plurality of multipliers is utilized, according to our invention, the output currents therefrom may be so "mixed" as to give complete control of picture shading and background. Such modifications, being reasonably obvious, need not be illustrated.

It will be apparent from a consideration of the foregoing description of our invention that more nearly noiseless amplification of television signals may be obtained thereby than through the use of conventional thermionic amplifiers. Furthermore, our improved system, since stray capacities to ground have substantially no effect upon the operation of the multiplier, enables the transmission of much finer detail than in systems heretofore known.

We are aware of many physical modifications of our device and many other possible uses thereof that at once will be apparent to those skilled in the art. Our invention, therefore, is not to be limited except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. An electric discharge device constituted by a container in which are disposed a mosaic of light sensitive elements and an electron gun, in combination with an electron multiplier, the vacuous space of the said container and multiplier being continuous.

2. The invention as set forth in claim 1 wherein the electron multiplier comprises a plurality of electrodes capable of secondary emission and means constituting an electron-lens for focusing secondary-electrons from one electrode to another.

3. The invention as set forth in claim 1 wherein the electron multiplier comprises a plurality of electrodes capable of secondary emission and means constituting an electron-lens intermediate two adjacent electrodes for focusing secondary electrons from one electrode to another, at least one of said electrodes being electrically connected to an element of said lens.

4. The invention set forth in claim 1, wherein the electron multiplier is constituted by an evacuated container in which are disposed a plurality of electrodes capable of secondary emission as well as means for focusing upon one of said electrodes electrons emitted from another of said electrodes, and wherein at least one of the electrodes and a portion of the focusing means adjacent thereto are constituted by intersecting substantially cylindrical elements.

5. An evacuated container in which are disposed a target, constituted by a plurality of photosensitive particles insulatingly supported upon a common element, and a gun for sequentially bombarding the particles with electrons to cause them to emit secondary electrons, in combination with an electron multiplier into which said secondary electrons may be drawn to therein cause the emission of still further secondary electrons, whereby the secondary emission currents from the target may be amplified.

6. The invention set forth in claim 5, wherein the electron multiplier is of the vacuous electrostatic type and wherein the vacuous space in the multiplier and the container are continuous.

7. The invention set forth in claim 5, wherein the electron multiplier is of the electrostatic type and is constituted by an evacuated appendage in which is disposed an electrode capable of secondary emission and an output electrode, the vacuous space in the container and the appendage being continuous and the secondary emissive electrode being accessible to secondary electrons originating in the container.

8. A combined secondary electron emissive electrode and electron focusing electrode constituted by a plurality of intersecting substantially cylindrical elements the inner surface of at least one of said elements being treated to enhance secondary emission.

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