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TELEVISION TRANSMITTING TUBE WITH A CONCAVE SECONDARY ELECTRON EMITTER

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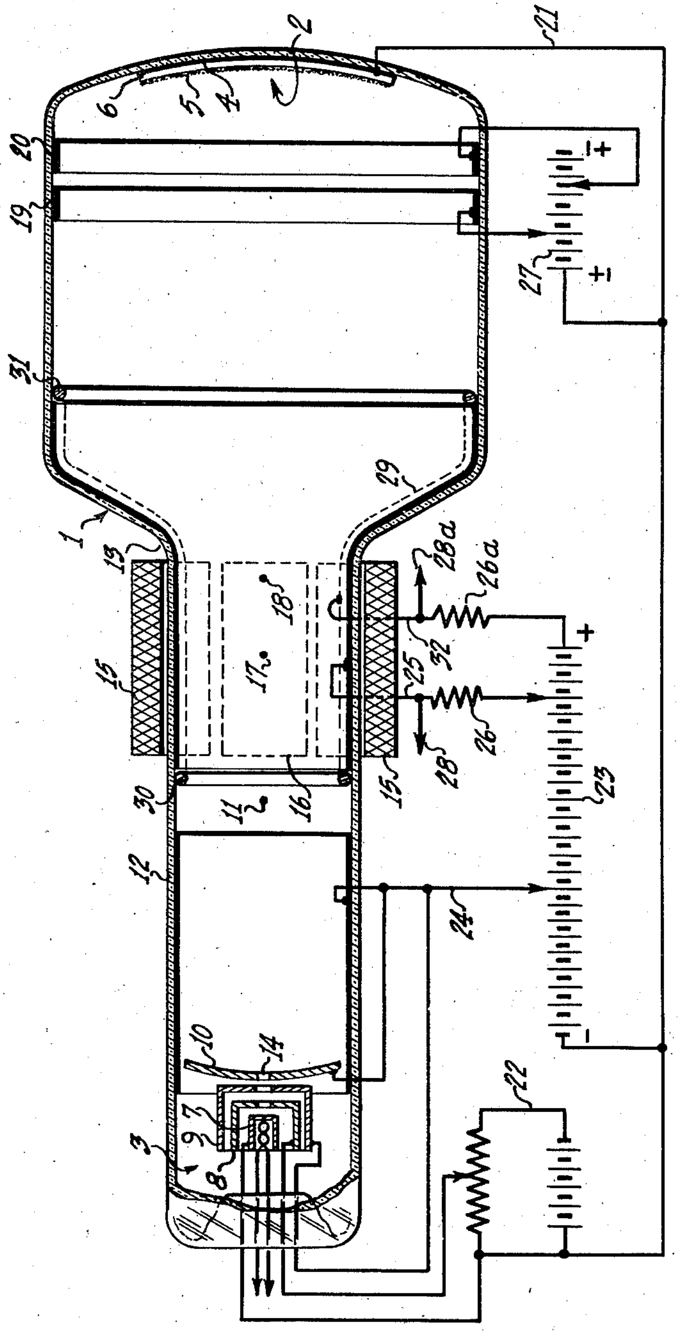

INVENTOR
HAROLD B. LAW
BY Charles McClair
ATTORNEY

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TELEVISION TRANSMITTING TUBE WITH A CONCAVE SECONDARY ELECTRON EMITTER

Harold B. Law, Princeton, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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My invention relates to television apparatus, tubes and systems and is concerned primarily with apparatus incorporating a tube in which an electron beam is scanned over a target to develop a stream of electrons which is multiplied by secondary emission phenomena in the absence of electro-magnetic beam focusing fields.

It has been customary in the art of television signal generation to develop the picture or video signal by directing an electron beam through a magnetic beam focusing field toward a target which is maintained at substantially the potential of the electron beam source, to rob the beam of electrons in accordance with an electrostatic charge replica of the optical image for which signals are desired, and to direct the remaining electrons to a secondary electron multiplier from which the signal may be generated. In such tubes it has been necessary, if the advantages of electron multiplication were to be obtained, to utilize a longitudinal magnetic field to focus and direct the electron beam upon the target and to return the excess electrons after the robbing action of the target along predetermined paths to the multiplier. The use of such a tube enables the development of a relatively strong picture or video signal but the use of the magnetic field generating means is often disadvantageous in compact television camera units and especially in applications where it is desired to combine a tube with reflection-type optical systems inasmuch as the magnetic means which surrounds the tube occupies considerable space and intercepts a large proportion of the light from the reflection optic. In addition, such use is disadvantageous in that a power supply of high quality must be provided for energizing the magnetic means with a steady current of exceptionally good regulation. While it has been proposed to utilize a low velocity television tube without the use of such magnetic means, it has not been possible to adapt such a tube to utilize the principles of secondary electron emission to increase the usable output picture or video signal.

It is an object of my invention to provide highly sensitive television apparatus capable of developing picture or video signals of high quality and high intensity. It is another object to provide a tube of the low velocity beam scanning type suitable for use with reflection-type optical systems utilizing secondary electron emission phenomena, and it is a further object to provide a light translating and scanning device which will simplify the development of television signalling impulses of high intensity with a minimum

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of distortional effects and without recourse to magnetic beam focusing. In accordance with my invention I provide apparatus comprising a tube wherein an electron beam may be developed and scanned over a target at low longitudinal velocities to develop a modulated electron beam in the total absence of magnetic directing and focusing fields and wherein excess electrons of the beam not reaching the target are directed to a secondary electron emitting electrode or electrodes in the total absence of magnetic electron beam focusing fields. These and other objects, features and advantages of my invention will become apparent upon consideration of the following description and the accompanying drawing wherein the single figure is a longitudinal sectional view of a tube made and operated in accordance with my invention.

As indicated above, tubes of the prior art capable of developing an intensified signal by secondary electron emission have been substantially limited by the use of a longitudinal magnetic field developed by a coil substantially enclosing the length of the tube, whereas tubes of the low velocity type wherein the electron beam is focused and directed solely by electrostatic means have not been adaptable to secondary electron multiplication of the electrons returning from the target. More particularly, in accordance with my invention I provide a tube structure wherein an electron beam is electrostatically focused upon a concave target, scanned over the target preferably from a center of deflection more remote from the target than the center of curvature thereof to develop a stream of electrons modulated in accordance with an optical electrostatic image replica on the target. The modulated stream of electrons from the concave target is then directed to a concave secondary electron emitting electrode, axially disposed with respect to the target and the deflection means, whereupon the intensified electron flow due to secondary multiplication is collected to develop an intensified signal. Still further in accordance with my invention I provide further secondary electron emitting means surrounding both the electron beam approaching the target and the excess electrons of the beam returning from the target and impinging the concave secondary emitter to provide further electron multiplication and consequently even greater signal strength.

Referring to the drawing, I have shown a tube made in accordance with my invention comprising an evacuated envelope 1 having at one end thereof a target 2 which is preferably of the charge storage type and at the opposite end of the envelope 1 an electron gun structure 3 for developing an electron beam. The target 2, if of the charge storage type, comprises a light transmitting electrode 4 and a mosaic 5 of photo-emissive elements separated from the electrode 4 by a very thin film of insulation 6. The electron gun structure 3 comprises the conventional indirectly heated electron emissive cathode 7, beam intensity control grid 8 and an apertured anode 9. In accordance with my invention I provide immediately adjacent the electron gun 3 a concave secondary electron emitting electrode or emitter 10 with its concave surface facing the target 2 and having a center of curvature 11 along the tube axis at a predetermined position between the emitter 10 and the target 2. Further in accordance with my invention I provide electron accelerating or focusing electrodes 12 and 13 likewise axially disposed and separated one from the other along the tube axis such that the region between the electrodes 12 and 13 surrounds the center of curvature 11 of the emitter 10. The purpose of this disposition of the electrodes 12 and 13 will be more fully appreciated hereinafter.

The secondary emitter 10 is of a material having a low work function, that is, high secondary electron emitting properties, and is provided with an aperture 14 axially aligned with the electron gun 3 and the tube and target axis, this aperture preferably being of very small diameter such as a diameter of 1 mil (0.001''). The electron beam developed by the electron gun 3 is directed through the aperture 14 and limited in diameter thereby, the electrons of this beam then being focused by a field developed between the anodes 12 and 13 upon the target 2. Further in accordance with my invention I provide deflection means such as a pair of horizontal deflection coils 15 and a pair of vertical deflection coils 16 intermediate the emitter 10 and the target 2, preferably surrounding the tube in the region of the anode 13, these coils being so positioned that the effective center of deflection 17 is at a position along the tube axis more remote from the target than the spherical center of curvature 18 of the target. Thus I have found my electrode combination particularly effective for secondary electron multiplication with a positioning of the centers of curvature 11 and 18 and the center of deflection as described above. With this positioning of the electrode structure I prefer to provide one or more additional focusing electrodes immediately adjacent the target 2 such as the ring electrodes 19 and 20. With the described positioning, the electron beam is deflected over paths oblique to the target surface, whereupon the ring electrodes 19—20 direct the beam normal to the target surface, that is, radially to the spherical surface whose center of curvature is at the point 18.

In general, the electrodes are maintained at operating potentials such that the light transmitting electrode 4 is at or near the potential of the cathode 7 such as by the direct electrical connection 21, the control grid 8 being maintained at a conventional control potential such as developed by the potentiometer-potential source combination 22, the anode 9 being maintained positive thereto by a battery or other potential source 23. Preferably the emitter 10 is maintained at a positive potential with respect to the anode 9, although the anode 9 may be omitted altogether, in which event the emitter 10 serves as the anode for the electron gun. Preferably, although not necessarily, the emitter 10 is maintained at the same potential as the anode 12 by the potential lead 24 connected to the source 23. The further anode 13 is likewise maintained at a more positive potential than the foregoing electrodes by a potential lead 25 in which the output impedance 26 may be connected as shown, while the electrode rings 19 and 20 are maintained at slight positive or negative potentials with respect to the cathode 7 and the light transmitting electrode 4 by an auxiliary potential source 27.

As a particular example of a tube made in accordance with my invention, the axial distance between the center of deflection 17 and the target was made equal to 4 inches with a radius of curvature of the target of 3 inches. Good secondary electron emission was obtained from the emitter 10 by placing this electrode at an axial distance of 6½ inches from the target 2 with its center of curvature 11 at an axial distance of 4 inches from the target. For this construction the anodes 12 and 13 have a minimum diameter of 1⅛ inches when using a rectangular target measuring ⅞ x 1⅛ inches. In addition, the anode 12 is made to preferably extend beyond the emitter 10 in the direction of the electron gun, the axial length of this anode from the emitter toward the target being 2 inches, the center of curvature of the emitter 10 lying along the axis and midway between the anodes 12 and 13.

In accordance with my invention I further provide an electrode structure which will allow electrons returning from the target to flow unimpeded to the secondary electron emitter. For proper tube operation the electrons returning to the emitter 10 from the diagonal corners of the target must pass through the anodes 12 and 13. Consequently, I have found a maximum ratio of the maximum useful target dimension to anode diameter to exist. For a ratio above this limit the electrons are not efficiently collected. This maximum ratio is 1.30, which means that for a rectangular projection spherical target the target diagonal measured as a chordal distance may be up to 1.30 times the minimum diameter of the anodes 12 and 13.

For the structure described immediately above I have found the following potentials, all given with respect to the cathode, to be satisfactory in providing both good resolution and high signal strength, these potentials being as follows:

	Volts
Cathode	0
Grid 8	—9
Anode 9	175
Emitter 10	175
Anode 12	175
Anode 13	1500
Ring electrodes 19—20	100
Target electrode 4	0

In the operation of the tube and system shown in the drawing, an optical image of the picture to be transmitted is focused on the target 2 preferably by a reflection-type optical system (not shown) such as of the Schmidt type to liberate electrons in response to the elemental areas of light and shade, thereby developing an electrostatic image replica of the optical image made up of positive charges due to the loss of electrons. The formation of this electrostatic image replica may be accomplished in a number of equivalent ways such as by directing an electron image on the target, in which event the target is preferably of the double-sided type, it being appreciated that the manner in which the electron image is formed involves no part of my present invention. Since the light transmitting electrode 4 is maintained at or substantially at cathode potential, the electron beam developed by the electron gun 3 approaches the target 2 with substantially zero longitudinally velocity and is directed radially of the target by adjusting the potentials applied to the ring electrodes 19 and 20 such as by the potential source 27. In the passage of the electron beam between the gun and the target the electrons are directed so as to be focused on the target and scanned over the target in conventional manner by the deflection coils 15 and 16. The positioning of these coils so that the center of deflection 17 is more remote from the target than the center of curvature 18 in combination with the fields produced by the ring electrodes 19 and 20 provides substantially normal incidence of the electron beam on the target 2, notwithstanding its very low velocity. As the beam becomes incident on the target which is electrostatically charged over elemental areas in accordance with the light and shade areas of the optical image, the positive charges will be neutralized. Assuming the beam from the gun 3 is of relatively high intensity, that is, capable of discharging the most positively charged areas of the target, the electrons in excess of those required to neutralize less positively charged target areas will be unabsorbed by the target. These excess electrons are directed by the electrostatic field developed between the target and the ring electrodes 19 and 20 longitudinally of the tube. Surprisingly, these excess electrons are not collected by the anode 13 apparently because the electrostatic fields developed between the target and the ring electrodes in combination with the target curvature cause these electrons to follow paths over which the field of the anode 13 is ineffective in drawing these electrons toward the anode. Consequently, the electrons continue along paths toward the electron gun and are focused by the electrostatic field between the anodes 12 and 13 upon the emitter 10. By actual observation of the picture replica I have found that with adjustment of the potentials applied to the ring electrodes 19—20 the returning electrons from the extremities of the target actually cross over in front of the emitter 10 and impinge thereon. As described above, I maintain the emitter 10 at a positive potential with respect to the cathode and the target 2 so that these excess electrons returning in the direction of the emitter 10 have relatively high velocity upon impingement therewith. The emitter 10, being of a material capable of high secondary electron emission, develops secondary electrons but these secondary electrons due to their initial emission velocities are not collected by the anode 12 inasmuch as this anode is at the same potential as the emitter 10, and the field developed between the anodes 12—13 penetrates the space within the anode 12. I have found a limiting potential of 200 volts between these anodes sufficient to withdraw the secondary electrons from the emitter 10, but since in normal operation this difference of potential is much greater, 1325 volts in the above example, no difficulty is experienced in withdrawing these secondary electrons. In addition, the secondary electrons are defocused by this field in such a manner that the secondary electrons are collected by the anode 13. In fact, some of these

secondary electrons may approach the target, but being unable to be collected by the target return to the anode 13 in a defocused state.

From the above description of the apparent operation of my tube it will be appreciated that with a constant electron beam intensity and for a given quantity of picture modulated electrons returning from the target a greater quantity of electrons likewise being picture modulated will be liberated by the emitter 10 and collected by the anode 13. Consequently, an intensified signal may be developed across the output impedance 26 which may be applied to an amplifier as indicated by the arrow 28. However, and still further in accordance with my invention I am able to obtain an even greater secondary electron intensification by providing a second stage of electron multiplication prior to final collection of the electrons. Thus as shown in the drawing, I provide an electron collecting electrode 29 of perforated formation adjacent the anode 13. As shown in the drawing, the electrode 29 may take the form of a coarse wire mesh conforming to the surface of the anode 13 but of slightly smaller diameter and supported in insulated relation to the anode 13 by ring members 30 and 31 at either end along the tube axis, these rings bearing on the tube wall. The electrode 29 is maintained slightly positive with respect to the anode 13 by the potential source 23 and in this mode of operation the anode 13 serves as a second secondary electron emitter. I have found that when utilizing this additional structure the secondary electrons liberated at the emitter 10 are accelerated by and impinge upon the anode 13 which now serves as a second secondary emitter with sufficient velocity to liberate further secondary electrons which are in turn collected by the collector 29. Since, when using the collector 29, the effective diameter of the neck portion of the tube is reduced, the effective useful area of the target may also be slightly reduced to meet with the above-described limiting ratio for target diagonal to anode opening. For this mode of operation I prefer to provide the output impedance in series with the potential lead 32 as shown at 26*a*, in which event the impedance 26 is removed from the lead 25, the signal across the impedance 26*a* being applied to an amplifier through the lead 28*a*. My invention should not be confused with tubes wherein the electron beam impinges on the target with high longitudinal velocity. In such tubes secondary electrons having random emission velocities are developed at the target surface, it being exceedingly difficult to focus these electrons to an adjacent secondary electron multiplier. My structure is wholly unsuited for such operation because the random velocity of the electrons prevents their efficient collection such as by the emitter 10. However, in low velocity operation the electrons approach and the picture modulated electrons leave the target along paths substantially normal to the target surface, my structure being specifically adapted to multiply such electrons efficiently for the development of high intensity signals.

From the above description of my invention it will be apparent that I have provided apparatus whereby efficient secondary electron multiplication may be obtained in a low velocity beam scanning tube without recourse to conventional electro-magnetic beam focusing coils and that while I have described the preferred embodiments of my invention and the preferred modes of operation, various other modifications and alternate structures embodying my invention may be provided without departing from the scope of my invention as set forth in the appended claims.

I claim:

1. Apparatus for television transmission comprising a tube having an electron gun to develop an electron beam, an oppositely disposed target positioned transversely to the axial path of said beam, beam deflection means to scan said beam over said target, means between said electron gun and said beam deflection means comprising a concave secondary electron emitter with its center of curvature lying along said axial beam path to receive electrons of said beam not reaching said target and develop secondary electrons and means between said secondary emitter and said beam deflection means to collect secondary electrons from said emitter.

2. Apparatus for television transmission comprising a tube having an electron gun to develop an electron beam, an oppositely disposed target positioned transversely to the axial path of said beam, electrostatic beam focusing means between said electron gun and target, said means being the sole factor in focusing said beam on said target and the electrons of said beam not reaching said target upon an area closely adjacent said electron gun, beam deflection means to scan said beam over said target, means closely adjacent said electron gun comprising a concave secondary electron emitter with its center of curvature lying along said axial beam path to receive electrons of said beam not reaching said target and focused thereon by said electrostatic means to develop secondary electrons, and means including a portion of said electrostatic beam focusing means between said secondary emitter and said beam deflection means to collect secondary electrons from said emitter.

3. Apparatus for developing television signals comprising a tube having an electron gun to develop a high velocity electron beam, a charge storage target positioned transversely to the axial path of said beam, said target being concave with respect to said gun with its center of curvature lying along said axial path, means between said gun and said target to scan said beam over said target, a plurality of longitudinally spaced anodes between said gun and said target and a concave secondary electron emitter having a center of curvature lying along said axial path in a region between said spaced anodes to develop secondary electrons upon impingement of electrons of said beam not reaching said target for the development of television signals.

4. Apparatus for developing television signals comprising a tube having an electron gun to develop a high velocity electron beam, a charge storage target positioned transversely to the axial path of said beam, said target being concave with respect to said gun with its center of curvature lying along said axial path, means between said gun and said target to scan said beam over said target, a plurality of longitudinally spaced anodes between said gun and said target, an electrostatic beam focusing electrode adjacent said target, said spaced anodes and said electrode being the sole means between said gun and target for focusing said beam on said target, and a concave secondary electron emitter having a center of curvature lying along said axial path in a region between said spaced anodes to develop secondary electrons upon impingement of electrons of said beam not reaching said target for the development of television signals.

5. Apparatus as claimed in claim 4 including an additional electrode between said beam focusing electrode and said target, said electrodes and said spaced anodes being the sole means between said gun and said target for focusing said beam upon said target and the electrons not reaching said target upon said secondary electron emitter.

6. Television apparatus comprising a tube enclosing an electron gun to develop an electron beam, a light sensitive target adapted to develop elemental charges spatially distributed in accordance with the light and shade areas of an optical image, said target being concave toward said electron gun, a secondary emitter adjacent said gun and facing said target to receive electrons of said beam not collected by charged areas thereof, said emitter being concave toward said target, means to develop an electron lens at the approximate center of curvature of said emitter, said means including an anode adapted to receive secondary electrons from said emitter, deflection means between the emitter and the center of curvature of said target to deflect said beam over said target along paths oblique to said target and means to cause the electrons following deflection to approach, and electrons not reaching said target to leave said target along paths substantially normal thereto whereby said electrons leaving said target are directed toward said emitter.

7. Television apparatus comprising a tube enclosing an electron gun to develop an axially directed electron beam, a light sensitive target adapted to develop elemental charges spatially distributed in accordance with the light and shade areas of an optical image, said target being spherically concave toward said electron gun with its center of curvature lying on the axis of said beam, a secondary emitter adjacent said gun and facing said target to receive electrons of said beam not collected by charged areas thereof, said emitter being concave toward said target with its center of curvature on said axis between said emitter and said target, means to develop an electron lens at the approximate center of curvature of said emitter, said means including an anode adapted to receive secondary electrons from said emitter, deflection means having an effective center of deflection between the emitter and the center of curvature of said target to deflect said beam over said target along paths oblique to said target and means to cause the electrons following deflection to approach, and electrons not reaching said target to leave said target along paths substantially normal thereto whereby said electrons leaving said target are directed toward said emitter.

8. Television apparatus comprising a tube enclosing an electron gun to develop and direct a beam of electrons along an axial path, a spherically concave target of the mosaic light sensitive type positioned transversely of said axial path with its center of curvature along said path, said target being adapted to picture modulate said electron beam, a spherically concave secondary electron emitter adjacent said electron gun with its center of curvature at a predetermined position along said path, means to scan said beam over said target to develop picture modulated electrons incident upon said spherically concave emitter, an anode surrounding said path and extending substantially from said emitter to a region adjacent said predetermined position

along said path, a further secondary electron emitter surrounding said path and between said anode and said target, and an electron permeable secondary electron collecting electrode extending in overlying relation to said further emitter to collect electrons emitted by said further emitter for the development of television signals.

9. Television apparatus comprising a tube including an electron gun to develop an axially directed electron beam, a spherically concave target transversely positioned to the beam axis having an extended useful area of predetermined maximum chordal dimension, a secondary electron emitter adjacent said electron gun to receive electrons of said beam not reaching said target and an anode between said target and said emitter, the unobstructed opening in said anode measured in a direction transverse to said axis having a definite relation such that the ratio of said chordal dimension to said measured opening is not greater than 1.3.

10. Television apparatus comprising a tube including an electron gun to develop an axially directed electron beam, a spherically concave target positioned transversely to the beam axis having an extended useful area of predetermined maximum chordal dimension, a spherically concave secondary electron emitted adjacent said electron gun with its center of curvature along the beam axis to receive electrons of said beam not reaching said target and a cylindrical anode between said target and said emitter with an unobstructed opening to allow electrons not reaching said target to be directed upon said emitter, the unobstructed opening in said anode measured in a direction transverse to said axis having a definite relation such that the ratio of said chordal dimension to said measured opening is not greater than 1.3.

11. Television apparatus comprising a tube enclosing an electron gun to develop and direct a beam of electrons along an axial path, a spherically concave target of the mosaic light sensitive type positioned transversely of said axial path with its center of curvature along said path, said target having an extended useful area of predetermined maximum chordal dimension and being adapted to picture modulate said electron beam, a spherically concave secondary electron emitter adjacent said electron gun with its center of curvature at a predetermined position along said path, means to scan said beam over said target to develop picture modulated electrons incident upon said spherically concave emitter, an anode surrounding said path and extending substantially from said emitter to a region adjacent said predetermined position along said path, a further secondary electron emitter surrounding said path and between said anode and said target, and an electron permeable secondary electron collecting electrode extending in overlying relation to said further emitter to collect electrons emitted by said further emitter, said further emitter and said collecting electrode having unobstructed openings measured transversely to said axial path such that the ratio of said chordal dimension to said measured openings is not greater than 1.3.

HAROLD B. LAW.