

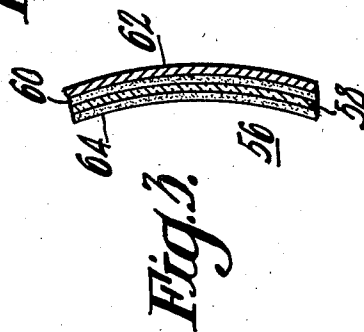
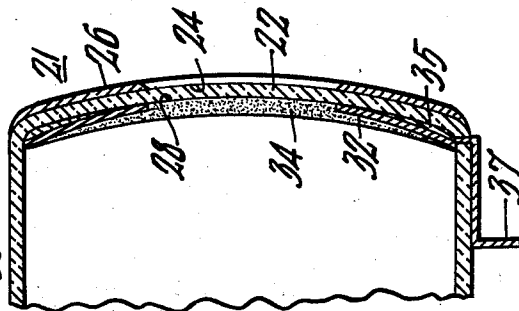
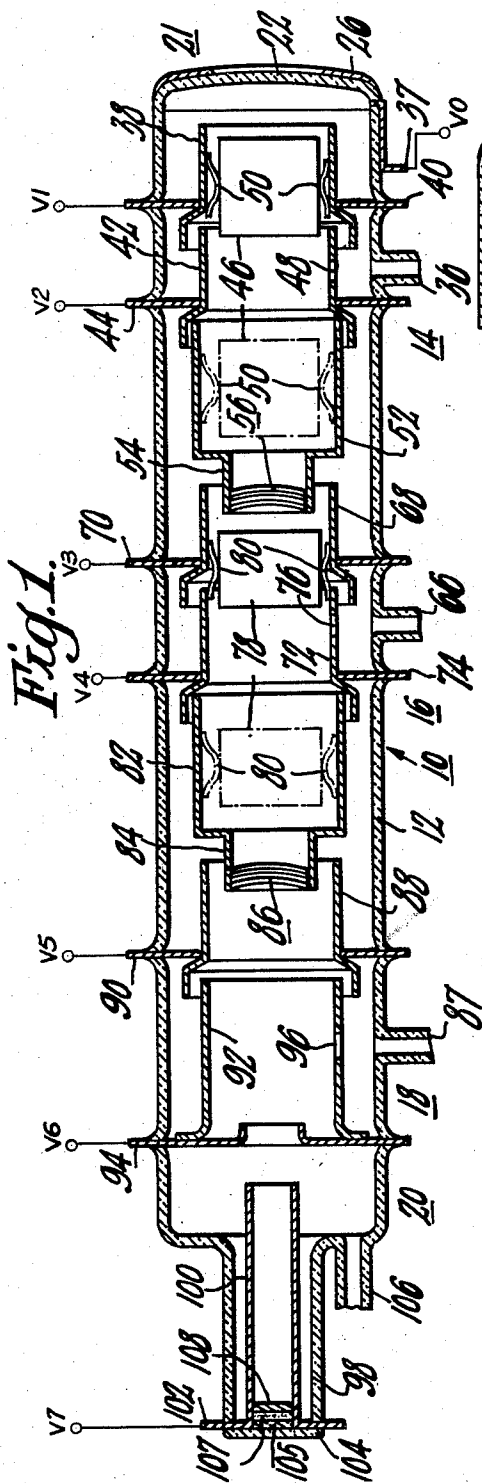
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IMAGE TUBE

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2,851,625

IMAGE TUBE

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This invention relates to an electron optical image or viewing tube and more particularly to image tubes in which an electron image from a target is amplified through a plurality of image amplifiers and is focused upon a fluorescent screen or other viewing device.

Electron tubes of the type under consideration include a photocathode which is adapted to emit a layer of electrons grouped in a pattern representative of an object "seen" by the photocathode. This layer of electrons is termed an "electron image." The electron image travels through the tube under the influence of control and accelerating electrodes toward a fluorescent screen-photocathode combination which, in turn, produces an amplified electron image. The amplified electron image may be further amplified and directed, finally, to a phosphor viewing screen on which an image of the object is viewed.

It is desirable in certain applications to have an object viewing electron tube which will operate under low lighting conditions with high sensitivity and high gain of the order of 1000. There are many types of image tubes which may be used for viewing objects. However, such tubes are generally too insensitive and have too low gain to be used for viewing objects in low light. Sensitivity is measured by the light output from the phosphor viewing screen compared with the light input to the photocathode from the object to be viewed. The sensitivity of these tubes may be increased if they are operated at higher voltages. However, the advantages gained by such operation are offset by the added problems attendant on high voltage operation. One problem is cold emission which is electron emission from metallic surfaces in a high potential field. This problem is discussed further below. Furthermore, even if these known viewing tubes are operated with higher voltages, the sensitivity and gain still fall short of that desired and required under certain conditions.

Accordingly, the principal object of this invention is to provide an improved image viewing electron tube having high sensitivity and high gain.

A further object is to provide an improved and efficient image viewing tube for viewing an object in very low light.

Another object is to provide a sensitive, high gain viewing tube which may be operated without excessive potential differences between any of its component parts.

In general, the purposes and objects of this invention are accomplished by the provision of an electron tube having a photocathode at one end and a plurality of electron image amplifying stages or sections disposed along the tube. Further means are provided for reducing light feedback between the various stages, an important factor influencing the gain of such a tube. By this expedient, high gain may be achieved without the use of excessively high potential differences between any of the components of the tube.

In the drawing,

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Fig. 1 is a longitudinal section, of an electron tube made according to this invention;

Fig. 2 is an enlarged sectional view of the photocathode window of the tube; and,

Fig. 3 is a sectional view of a portion of one of the fluorescent screen-photocathode combinations in one of the image amplifying sections of the tube.

Referring to Fig. 1, in accordance with the invention, there is shown an image intensifying tube 10 comprising an evacuated, generally cylindrical envelope 12 having a window in each end. Between the windows are a plurality of image amplifying devices and a plurality of electrodes for focusing an electron image. An electron image is a substantially planar distribution of electrons emitted by a photocathode and representative of incident radiation from an object energizing the photocathode. In this embodiment, the tube comprises four sections, a first section 14 which receives radiation directly from an object to be viewed and which emits an electron image of the object, second and third sections 16 and 18 for receiving said electron image and transmitting an amplified electron image thereof, and a fourth section 20 for further intensifying and finally viewing the image.

Each of the above-mentioned sections contains a plurality of focusing and accelerating electrodes which have electrical connections through the wall of the envelope to outside sources of voltage for biasing them. The first two sections 14 and 16 also contain cylindrical shield members which are provided for a purpose which is to be described below. The first three sections are provided with side tubulations extending from the wall of the envelope 12 contained by that section. The side tubulation is utilized during manufacture of the tube for inserting a device for evaporating photoelectric material onto the photocathode target, or image amplifier, in each section. The electrodes adjacent to the side tubes are provided with suitable apertures through which the evaporator device may be inserted. Detailed description of the foregoing elements is set forth below.

Referring specifically to each section of the device in turn, section 14 is the image receiving portion of the tube. This section comprises broadly, a photosensitive member or photocathode 21 and focusing and accelerating electrodes for controlling an electron image. In detail, and referring to Figs. 1 and 2 the photosensitive portion of the section 14 comprises a window 22 which may be the face plate portion of the tube envelope 12. The outside surface 24 of the window 22 is provided with an annular-shaped layer 26 of aquadag or some other suitable coating for restricting the amount of light which is passed into the tube 10 through the window 22. The inside surface 28 of the window 22 is provided, near its edges and adjacent to the cylindrical envelope portion 12 of the tube 10, with a thin coating 35 of a metal such as silver. This silver coating is formed, for example, by painting on a mixture of silver particles in a suitable binder. After application, the layer is baked to harden it and to remove the binder. An annular layer of platinum 32 is coated on the silver and extended radially toward the center of the rear surface 28 of the window 22 leaving a clear area having the size of the desired light image. The platinum layer is applied as a mixture of platinum chloride and is baked to produce the desired film. A layer 34 of photoemissive material such as caesium activated antimony is then deposited over the two layers 32 and 35 so that it covers the entire inside surface of the window 22.

Other suitable photoemissive surfaces may be used. The photoemissive surface is evaporated on to the glass window by any suitable method. One example of a suitable method and apparatus for this procedure is shown in a copending Ruedy application, Serial Number 306,601, filed August

27, 1952 now U. S. Patent No. 2,744,808, and assigned to the assignee of this application. According to this method, an evaporator carrying the materials to be evaporated is inserted into the tube envelope 12 through a side tubulation 36 part of which is shown in Fig. 1. When thus inserted, the evaporator and the photoemissive material carried thereby are heated and the material is evaporated onto the target, which in this case is the partially coated surface 28 of the window 22.

To provide bias voltage for the photocathode 34 of the photosensitive member 21, a suitable connection is made from the silver coating 35 to a voltage source (not shown) outside the tube envelope 12. One such suitable connection is a strip, ribbon, or wire 37 of electrically conductive material which is embedded in the wall of the tube envelope. The end of the ribbon 37 outside the envelope is connected to the voltage source and the end within the envelope is connected to the silver coating 35. A voltage V_0 may thus be applied to the photocathode 34.

A suitable electron optical system is provided in the first section 14 for focusing and accelerating the electron image produced by the photocathode 34 onto the image receiving assembly of the next section of the tube. Such electron optical system comprises a cylindrical electrode 38 mounted in the tube envelope 12 adjacent to the photocathode 21. The electrode is thus mounted by connection to a conductive annulus or ring 40 which is sealed in and extends through the wall of the envelope. Another similar cylindrical electrode 42 is similarly mounted adjacent to the electrode 38 by connection to a conductive ring 44 which is sealed in the wall of the envelope 12. Bias voltages V_1 and V_2 are applied to the electrodes 38 and 42 from the voltage source. The electrode 42 is provided with an opening 48 through which the evaporator (not shown) may be inserted when the photocathode 21 is prepared. A cylindrical conductive member 52 is connected to the electrode 42 as an extension thereof. The member 52 is provided with a narrowed cylindrical portion 54 which forms a support for a photocathode-phosphor screen assembly 56 of the next portion of the tube, section 16.

The photocathode-phosphor screen assembly 56 (Fig. 3) in section 16 comprises a glass base 58 which has a phosphor screen 60 coated on the convex surface thereof before it is inserted in the tube. The phosphor surface is metallized or otherwise coated with a light-opaque, electron-transparent layer 62 to prevent transmission of light back to the first section of the tube and to prevent its contamination by the caesium used to activate the photocathode 34. A layer 64 of photoemissive material is evaporated or otherwise deposited on the concave surface of the glass plate 58 and in electrical contact with electrode 54 after the plate has been mounted in the tube. The phosphor and the photoemissive material provide an optimum functional combination if they are selected to have their maximum spectral light emission and photo-response respectively at substantially the same frequency or wavelength of radiation. One such suitable combination is a zinc sulfide phosphor screen 60 and a caesium activated antimony layer 64. The photoelectric layer is deposited here again according to conventional procedure by inserting an evaporator through a side tubulation 66 provided in the wall of the envelope 12.

A cylindrical electrode 68 is mounted in the tube envelope 12 adjacent to the photocathode 64 of the assembly 56. The electrode 68 is mounted similarly to the electrode 38 by connection to a conductive ring 70 embedded in the wall of the envelope 12. A potential V_3 is applied thereto from a connection to the voltage source through the ring 70. A cylindrical electrode 72 similar to the electrode 42 is similarly mounted adjacent to the electrode 68. The electrode 72 is connected to a conductive ring 74 which is mounted in the wall of the envelope 12. The electrode 72 is provided with an opening 76

through which an evaporator may be inserted when the photoelectric layer of the assembly 56 is deposited. This operation is similar to that described for section 14. The electrode 72 is provided with a suitable voltage V_4 from the voltage source which is connected to the ring 74. A cylindrical conductive member 82 is electrically connected to the electrode 72 as an extension thereof. The member 82 is provided with a rearwardly extending cylindrical portion 84 of smaller diameter which forms a support for a photocathode-phosphor screen assembly 86.

Thus the next section 18 is introduced by the assembly 86 which is similar in construction to the photocathode-phosphor screen assembly 56. The photoelectric materials are evaporated as described above by the insertion of an evaporator (not shown) into a side tube 87. The section 18 is provided with a first cylindrical electrode 88 which is connected to a ring 90 embedded in the wall of the envelope 12. Electrode 88 is similarly suitably biased by a voltage V_5 . A cylindrical electrode 92 is provided with a connection to an annular ring 94 similarly connected to the wall of the envelope 12. A bias potential V_6 is applied to the electrode 92 through the ring 94. The electrode 92 is also provided with an aperture 96 through which the above-mentioned evaporator assembly (not shown) may be inserted when the photocathode of the assembly 86 is formed. Since the electrodes 88 and 92 do not have a large potential difference applied between them a shield similar to those previously described is not necessary in this section. The conductive rings 40, 44, 70, 74, 90, 94 which are sealed into the tube envelope 12, are used, as described, for electrical contact elements. In addition, the rings function as blocking partitions to prevent light from feeding back, by internal reflection along the tube wall, to where it might activate any one of the photocathodes of the assemblies 56, 86 or 21 and cause spurious photoemission.

The final section 20 of the tube 10 constitutes the image viewing portion of the tube and comprises a narrow portion 98 of the envelope 12 which terminates in a viewing screen for viewing the image. The viewing screen comprises a glass window 104 which is sealed to the envelope by means of a conductive ring 102. The other elements of the viewing screen are carried adjacent to the window 104 by a tubular electrode 100 which is connected to the ring 102 and serves to direct the electron image to the viewing screen. A suitable voltage V_7 is applied to the electrode 100 through the ring 102. The portions of the viewing screen carried by the electrode 100 are a transparent viewing disk 105, for example a glass disk mounted inside the cylinder 100 and in contact with the window 104; a phosphor screen 107, for example of zinc sulfide phosphor, deposited on the inner surface of the disk 105; and a coating 108 of light reflecting electron pervious material, for example aluminum, applied to the inner free surface of the phosphor screen 107. The phosphor screen and aluminum coating 108 may be deposited by any suitable method.

The image viewing portion of the tube is designed to concentrate the electron image to obtain high light emission per unit area of viewing screen. The desired degree of concentration is achieved by focusing the electron image emitted by the last photocathode onto a smaller area than that of the photocathode. The concentration may be to any desired degree and is limited only by the method of viewing desired. If it is convenient to use a microscope or similar means in association with the viewing screen, then the cross sectional area of the viewing screen and the electrode 100 might be quite small. If it is desired to view the image with the naked eye then a larger viewing screen is desirable. For the latter type of viewing, a screen and electrode having a diameter approximately one half that of the last photocathode is convenient.

An exhaust tube 106 is provided in the wall of sec-

tion 20 for exhausting the envelope 12 during processing of the tube. After the necessary processing steps, e. g. baking, degassing and the like, have been carried out, all of the side tubes 36, 66, 87 and 106 are sealed off in conventional fashion.

It is well known that conductive surfaces emit electrons when present in a high potential field even if the surface is cold. Such phenomenon is known as cold emission or high field emission. These emitted electrons may be accelerated by the electric field so as to (1) collide with residual gas atoms or molecules within the tube and produce positive ions, which in turn may be accelerated by the electric field and strike the cathode thus causing spurious electrons to be emitted therefrom, or (2) the electrons may strike the glass walls of the tube and thereby produce light by phosphorescence. This light may reach one of the photocathodes and produce spurious photoemission therefrom.

To avoid cold emission from the surfaces of the electrodes between which there are comparatively high electric fields, for example between electrodes 38 and 42 and between electrodes 68 and 72, care must be exercised in evaporating the photoelectric material in the vicinity of these electrodes since contamination of the metal surfaces increases cold emission. The aim is to so apply the coating that none of evaporated chemical is deposited on the electrodes or other surfaces of the tube in the regions of high electric fields. To this end, cylindrical shields 46 and 78 are provided to prevent such detrimental deposition. During the evaporation process, the shields are positioned as shown in Fig. 1 whereby the electrodes 38, 42 and 68, 72 are shielded from the material being evaporated. A shield is not required in section 18 since there are ordinarily no potential differences therein high enough to cause cold emission.

After the photocathodes of the assemblies 21 and 56 have been formed the cylindrical shields 46 and 78 are moved to positions in field free spaces as shown by the broken lines. Thus, the shields, having performed their function have no adverse effect on the operation of the tube. The shields may be moved merely by tipping the tube and allowing the shields to fall into the desired position where they are held by spring members 50 and 80 connected to the shields.

In operation of the device, radiation from an object is received at the photocathode assembly 21. Light striking the photoelectric layer 34 stimulates the layer to produce an electron image of the object which travels along the tube under the influence of the electrodes 38 and 42. The image forming electrons penetrate the metallic coating on the photocathode assembly 56 and excite the phosphor layer 60. Light from the phosphor layer passes through the thin glass sheet 58 to the photoemissive layer 64. Because the glass layer is quite thin there is little loss in image resolution from the phosphor layer 60 to the photoemissive layer 64 and full advantage is taken of the matching responses of the zinc sulfide phosphor and the antimony-caesium photoemissive layer to produce amplification.

Thus an amplified electron image is transmitted from the assembly 56 and travels along section 16 to the next photocathode assembly 86 where a similar amplification of the image takes place. Finally, the electron image energizes the phosphor screen 107 and the object is viewed through the window 104. The amplified electron image emanating from the antimony caesium layer of the photocathode assembly 86 is reduced in size by the electron optics of the final imaging section 20 to approximately one half of the previous image diameters. This concentration of the image into the smaller area of the phosphor screen 107 provides an additional brightness gain of approximately four times in the viewed object.

In one operative embodiment of the invention, the electrode voltages employed were as follows: V_0 as the reference voltage was a few volts positive or negative;

V_1 was V_0+0 to 50 volts; V_2 was V_0+ approximately 10,000 volts; V_3 was V_2+0 to 50 volts; V_4 was V_0+ approximately 20,000 volts; V_5 was V_4+0 to 50 volts; V_6 was V_4+ approximately 2000 volts; and V_7 was V_0+ approximately 30,000 volts.

It is clear from the foregoing discussion that this invention provides an image viewing tube which provides high sensitivity and high gain without the need for excessively high potential differences between any of the components of the tube.

What is claimed is:

1. An image device comprising an evacuated envelope having a photocathode at one end for forming an electron image representative of an object to be viewed and a phosphor viewing screen at the other end, means between said windows for amplifying an electron image passing therebetween, said amplifying means including a plurality of photocathode assemblies comprising a transparent base plate having on one side a phosphor layer coated to prevent light passage and on the other side a layer of photoemissive material, a plurality of coaxial electrodes mounted in operative relation with each photocathode assembly for accelerating and focusing said electron image, and a plurality of conductive rings mounted between the wall of said device and said electrodes for applying operating voltages to said electrodes and for preventing light feedback between said plurality of photocathode assemblies.

2. An image device comprising an envelope having a window at each end, a photocathode on one window for developing an electron image representative of an object to be viewed and a phosphor screen on the other window, a plurality of electron lens elements between said windows for accelerating and focusing said electron image, said electron lens elements comprising a plurality of cylindrical electrodes spaced from one another along a common axis and having their outside diameters smaller than the inside diameter of the wall of said envelope, a plurality of photocathode assemblies within said cylindrical electrodes for intensifying said electron image, means within said cylindrical electrodes and forming part of said photocathode assemblies for preventing the transmission of light in the return direction through said cylindrical electrodes, and means disposed in the space between the inner wall of the envelope and the outer walls of said cylindrical electrodes for preventing the transmission of light in the return direction by internal reflection along the envelope wall.

3. An electron tube comprising an envelope, a photocathode at one end for producing an electron image in response to incident radiation, a hollow cylindrical electron lens system adjacent to said photocathode and having an open end remote from said photocathode, a screen disposed within said open end of said electron lens system for converting said electron image to a visible light image, means coupled to said screen for preventing light feedback from said screen to said photocathode, and annular electrode means surrounding said electron lens system and blocking the feedback path of light between said screen and said photocathode.

4. An electron image tube comprising an envelope, a photocathode at one end for producing an electron image in response to incident radiation, a hollow cylindrical electron lens system adjacent to said photocathode and having an open end remote from said photocathode, a screen disposed within said open end of said electron lens for converting said electron image to a visible light image, the space within said lens system between said photocathode and said screen defining a path of travel for said electron image, a light-reflecting film on said screen and facing said photocathode for preventing light feedback to said photocathode, and an annular electrode surrounding said electron lens system and disposed between said lens system and said envelope for preventing feedback

of light to said photocathode along a second path outside
of said path for said electron image.

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