April 17, 1962

H. W. G. SALINGER

3,030,514

IMAGE INTENSIFIER

Filed Feb. 8, 1960

Fig. 1.

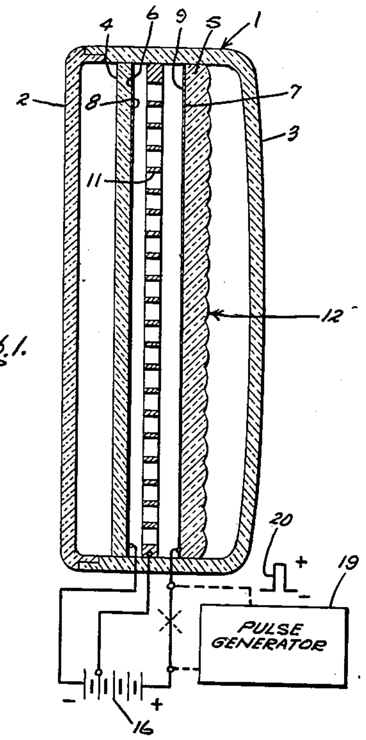


Fig. 2.

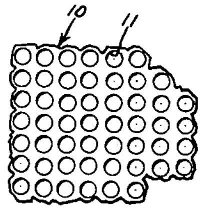


Fig. 3.

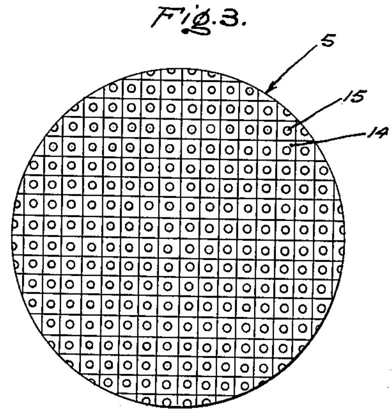


Fig. 4.

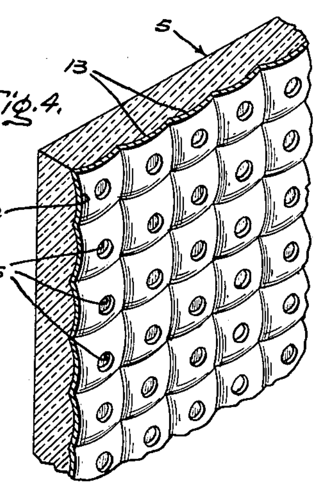
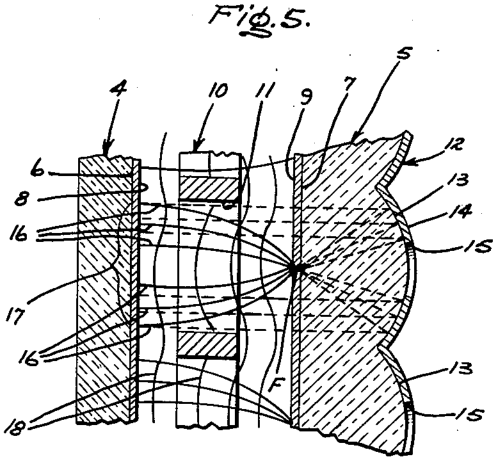


Fig. 5.



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3,030,514

Patented Apr. 17, 1962

3,030,514

IMAGE INTENSIFIER

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Filed Feb. 8, 1960, Ser. No. 7,145
10 Claims. (Cl. 250—213)

The present invention relates to an image intensifier, and more particularly to an image tube in which an electron image from a photocathode is reproduced in visible form upon a fluorescent screen.

Image tubes of conventional design, such as those disclosed in Carlo Patent #2,774,002 and Lindsay Patent #2,872,315, use photoelectric cathode and phosphor anode elements spaced part in such position that an electron image produced by the photoelectric cathode can be extended to the phosphor anode. The cathode and anode elements normally face each other, such that light emitted by the phosphor anode ordinarily can reach the photocathode to produce further excitation of the latter. However, this feedback of light from the phosphor element to the photocathode has been deliberately avoided, different structures being used for this purpose. One such structure is illustrated in Carlo Patent #2,774,002 wherein an anode interposed between the photocathode and phosphor is provided with a mask having an aperture at the crossover point of the electrons. Since this aperture is small, very little, if any, of the light emitted by the phosphor element can return to the photocathode. Another scheme for preventing the light from the phosphor from reaching the photocathode is the aluminizing of the phosphor, this technique being conventional in the art of image and television picture tubes.

The present invention differs in at least one primary respect from these prior art tubes in that light emitted by the phosphor element is deliberately fed back to the photocathode. This produces increased emission by the photocathode which, in turn, increases the light output of the phosphor, this greater light output in turn being fed back to the photocathode. This obviously results in greater light output as compared with the output of the prior art tubes discussed above.

It is therefore an object of this invention to provide an image tube in which light feedback between the photocathode and phosphor is utilized to produce an intensified display.

It is another object of this invention to provide an image tube which utilizes light feedback internally of the tube for increasing the brightness of the display.

It is still another object of this invention to provide an image tube in which electron emission from elemental areas of the photocathode is restricted to impingement upon corresponding elemental areas of the phosphor, and light emitted by the latter phosphor areas in turn is limited to impingement upon the respective emitting areas of the photocathode. The entire tube may be considered, therefore, as being subdivided into a plurality of elementary image tube cells, each cell being composed of an elemental area of photocathode and a corresponding elemental area of phosphor.

In achieving the objects of this invention, an image intensifier is provided which comprises an evacuated envelope, first and second planar transparent supporting plates mounted in the envelope, said plates being parallel and in proximity to each other, the inner facing surfaces of these plates being parallel, a layer of photoelectric material on the inner surface of the first plate, a layer of transparent phosphor material on the inner surface of the second plate, a planar anode element of predetermined thickness interposed between both plates, this anode element having a plurality of apertures through

which electrons and light pass between the aforementioned facing surfaces. The outer surface of the second plate which carries the phosphor is divided into a plurality of spherically curved surfaces. These sperical surfaces are positioned in registry with the apertures in the anode element, and a layer of light-reflective material is provided on the spherical surfaces for reflecting light emitted by the phosphor rearwardly through said apertures and onto the photocathode. The spherical surfaces thus form mirrors, concave toward the inside, the focal points lying preferably in the plane of the phosphor layer. Viewing apertures are provided in the light-reflective material, there being one viewing aperture for each spherical surface. The image reproduced by the phosphor layer is observed through the viewing apertures. By reason of restricted light feedback between respective elemental areas of the phosphor and of the photocathode, an intensified image is displayed.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent and the invention itself will be best understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a longitudinal sectional illustration of one embodiment of this invention;

FIG. 2 is a front view of a portion of the apertured anode element;

FIG. 3 is a front view of the lenticulated surface of the glass plate which carries the phosphor layer;

FIG. 4 is a perspective illustration, in part section, of the phosphor plate of FIG. 3; and

FIG. 5 is a fragmentary, enlarged sectional illustration disclosing the operating elements of the tube, the paths of electron flow and light feedback being graphically portrayed.

Referring to the drawings, and more particularly to FIG. 1, an evacuated glass envelope, indicated generally by numeral **1**, is cylindrical in shape and provided with two transparent end plates **2** and **3**. Inside the envelope **1** are mounted two flat discs **4** and **5** of glass, these discs being positioned closely adjacent to each other with the inner faces **6** and **7**, respectively, thereof preferably being flat and parallel.

On the surface **6** is a layer **8** of photoelectric material containing cesium or other alkali metal. A suitable method of preparing this layer and the composition thereof are fully disclosed in Lindsay Patent #2,870,315. Many other suitable photoelectric layers are well known in the art.

On the surface **7** of the supporting disc **5** is a layer **9** of phosphor material, this material being of the usual composition such as zinc, ortho-silicate, or compounds containing zinc sulphide. Preferably, this phosphor layer **9** is transparent, or semi-transparent, and composed of a silver activated zinc sulphide which is evaporated by the usual techniques onto the surface **7**.

Interposed between the photocathode **8** and phosphor layer **9** in spaced parallelism therewith is a metallic, planar anode element **10** having a plurality of apertures **11**. These apertures are relatively small in size but relatively great in number, the element **10** thereby resembling a fine mesh screen.

The outer surface **12** of the supporting disc **5** is lenticulated, as more clearly shown in FIGS. 4 and 5, the surface being divided into a plurality of spherically curved surfaces **13**.

As shown more clearly in FIG. 5, each curved surface **13** corresponds in arcuate extent to the diameter of each anode aperture **11**. Further, each curved surface **13** is registered with a respective one of the anode apertures **11** for a purpose which will become apparent from the following description.

A layer **14** of light-reflective material, such as silver, is provided on the outer surface **12** of the supporting disc **5**, this layer being omitted in the centers of the spherically curved surfaces **13** to provide viewing apertures **15**. This layer **14** on each surface **13** therefore acts as a concave mirror for light emitted by the phosphor layer **9**, and preferably the focal point of each elementary mirror lies in the plane of the phosphor.

Referring to FIG. 1, circuit connections from a source **16** of supply voltage are made to the photocathode, the anode **10**, and the phosphor **9**, the voltage applied to the phosphor **9** being greater than that applied to the anode **10**. The magnitude of these voltages will appear from the following description.

Reference is now made to FIG. 5 for explaining the operation of the invention. With suitable voltages applied to the photocathode **8**, the anode **10** and the phosphor layer **9**, an electrostatic field is established which produces electron trajectories from the photocathode to the phosphor along the paths indicated by the family of lines **16**. When radiation falls on the photocathode **8**, electrons are emitted which follow these trajectories toward the phosphor layer **9** to cross over at the point F which lies in the plane of the phosphor.

The entire tube may be considered as being subdivided into a plurality of elementary image tube cells, each cell having its own electron-optical system which comprises the respective aperture **11**. Further, each cell comprises the elemental areas of photocathode **8** and phosphor **9** which are opposite each other in registry with the respective aperture **11**; these cells are operatively isolated from each other so that a description of operation of one cell will suffice for all.

One such cell is graphically illustrated in FIG. 5. As already explained, electrons emitted by the elemental area **17** of the cathode **8**, which area corresponds in size to that of the aperture **11**, are electrostatically focused or accelerated to a cross-over point F on the phosphor layer. This electrostatic focusing or acceleration is produced by the equipotential surfaces indicated by the lines **18**.

The phosphor **9** produces a spot of light at the point F in response to electron impingement, this spot of light being emitted in all directions. With the phosphor layer **9** transparent, the light from the point F will strike the mirror **13, 14** and will be reflected rearwardly in parallel rays to the photocathode area **17** because, as explained earlier, the curvatures of the elemental surfaces **13** are so chosen that F is the focal point of the respective curved surface **13**. The reflected light on the photocathode area **17** increases electron emission which is directed onto the phosphor point F. This feedback of light and increased emission continues until the phosphor reaches saturation brightness, at which point the brightness will not increase. The phosphor is observed through the viewing apertures **15**.

In a slightly different mode of operation, this feedback can be utilized for intensifying the display of a half-tone image by pulsing the cathode, anode **10** or phosphor **9** in such a manner that electron flow is interrupted at some point prior to the phosphor reaching saturation brightness. As shown in FIG. 1, a pulse generator **19** may be connected in series with the battery **16** to apply repetitive pulses **20** of voltage to the phosphor **9**. These pulses are of sufficient magnitude to cause the electrons emitted by the cathode **8** to impinge the phosphor **9** but are of a duration just short of that required to drive the phosphor to saturation brightness. In other words, the regenerative action of each elementary cell requires a finite time before the phosphor reaches saturation brightness; it is this time which determines the duration of the respective pulses **20**.

It is important that care be exercised to confine the emitted light to each respective elementary cell; the light

from phosphor element at F excites only that cathode element with which it is in registry. As has been shown, this condition is fulfilled for the light which is emitted from point F into the support layer **5**. Light which is emitted from point F toward the inside of the tube is prevented by the structure of the anode **10** from reaching adjacent cathode elements by arranging the geometrical parameters (side of apertures **11**, position and thickness of **10**) such that point F cannot "see" other parts of the cathode than the one with which it is in registry.

In an operative embodiment of this invention, suitable physical dimensions are as follows:

	Millimeters
Distance between photocathode **8** and anode **10**	1/2
Thickness of anode **10**	2
Distance between photocathode **8** and phosphor **9**	5
Thickness of glass plate **5**	1
Diameter of viewing apertures **15**	0.1
Diameter of each aperture **11**	1/2

Suitable operating potentials may be as follows:

Photocathode **8**	Ground potential.
Anode **10**	1,000 volts.
Phosphor **9**	10,000 volts.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

What is claimed is:

1. An image intensifier comprising first means which luminesces in response to electron bombardment, second means which emits electrons in response to radiation, said first and second means being disposed in proximity to each other whereby said first means will receive electrons from said second means and said second means will receive radiation from said first means, third means subdividing said first and second means into a plurality of elementary cells, each cell including an elemental portion of said first means and an elemental portion of said second means, said third means including light reflective means for reflecting radiation from said elemental portion of said first means to said elemental portion of said second means and for directing electrons from said elemental portion of said second means to said elemental portion of said first means thereby providing regenerative feedback between the individual cell areas.

2. An image intensifier comprising first means which luminesces in response to electron bombardment, second means which emits electrons in response to radiation, said first and second means being disposed in proximity to each other whereby said first means will receive electrons from said second means and said second means will receive radiation from said first means, third means subdividing said first and second means into a plurality of elementary cells, each cell including a portion of said first means and a portion of said second means, said third means including a planar anode means for directing electrons from each cell portion of said second means to the respective cell portion of said first means, said third means further including light reflective means for reflecting radiation from each cell portion of said first means to the respective cell portion of said second means, thereby providing regenerative feedback between the individual cell portions.

3. An image intensifier comprising a layer of phosphor, a layer of photoelectric material, said layers being disposed in proximity to each other whereby said phosphor layer will receive electrons from said photoelectric layer and said photoelectric layer will receive light from said phosphor layer, a planar anode means interposed between said layers for directing electrons from a plurality of elemental areas of said

photoelectric layer to respective elemental areas of said phosphor layer, and light-reflective means for reflecting light from said elemental areas of said phosphor layer to the respective elemental areas of said photoelectric layer, thereby providing regenerative feedback between the respective phosphor and photoelectric elemental areas.

4. An image intensifier comprising a layer of phosphor, a layer of photoelectric material, said layers being parallel and in proximity to each other whereby said phosphor layer will receive electrons from said photoelectric layer and said photoelectric layer will receive light from said phosphor layer, a planar anode element interposed between and parallel to said layers, said element having a plurality of apertures through which electrons from said photoelectric layer pass in transit to said phosphor layer, and mirror means for reflecting light from a plurality of elemental areas of said phosphor layer through respective ones of said apertures onto corresponding elemental areas of said photoelectric layer for providing light feedback to the latter.

5. An image intensifier comprising a layer of phosphor, a layer of photoelectric material, said layers being parallel and in proximity to each other whereby said phosphor layer will receive electrons from said photoelectric layer and said photoelectric layer will receive light from said phosphor layer, a planar anode element interposed between and parallel to said layers, said element having a plurality of apertures through which electrons from said photoelectric layer pass in transit to said phosphor layer, a transparent plate parallel to said photoelectric layer and having opposite surfaces, said phosphor layer being on the one of said surfaces facing said photoelectric layer, the other of said surfaces being divided into a plurality of adjoining curved surfaces, the plurality of curved surfaces being in registry with said apertures respectively, a layer of light-reflective material on said other surface for reflecting light emitted by said phosphor through said apertures and into said photoelectric layer, said plurality of curved surfaces having curvatures which reflect the light from adjacent elemental areas of phosphor through the respective adjacent apertures onto corresponding elemental areas of said photoelectric layer, and viewing apertures in the reflective material on said plurality of curved surfaces respectively.

6. An image intesifier comprising a layer of transparent phosphor, a layer of photoelectric material, said layers being parallel and in proximity to each other whereby said phosphor layer will receive electrons from said photoelectric layer and said photoelectric layer will receive light from said phosphor layer, a planar anode element interposed between and parallel to said layers, said element having a plurality of apertures through which electrons from said photoelectric layer pass in transit to said phosphor layer, a transparent plate parallel to said photoelectric layer and having opposite surfaces, said phosphor layer being on the one of said surfaces facing said photoelectric layer, the other of said surfaces being divided into a plurality of adjoining spherically curved surfaces, the focal points of said spherical surfaces lying substantially in the plane of said one surface, said spherical surfaces being in registry with said apertures, respectively, a layed of light-reflective material on said other surface for reflecting light emitted by said phosphor through said apertures and onto said photoelectric layer, and viewing apertures in the reflective material, there being one viewing aperture for each spherical surface.

7. An image intensifier comprising an evacuated envelope, first and second planar transparent supporting plates mounted in said envelope, said plates being parallel and in proximity to each other, the inner facing surfaces of said plates being parallel, a layer of photoelectric material on the inner surface of said first plate, a layer of transparent phosphor material on the inner surface of said second plate, a planar anode element of predetermined thickness interposed between said plates, said element having a plurality of apertures through which electrons and light pass between said facing surfaces, the outer surface of said second plate being divided into a plurality of spherically curved surfaces with the focal points thereof lying in the plane of said phosphor layer, said spherical surfaces being in registry with said apertures, respectively, a layer of light-reflective material on said other surface for reflecting light emitted by said phosphor through said apertures and onto said photoelectric layer, and viewing apertures in the reflective material, there being one viewing aperture for each spherical surface.

8. The image intensifier of claim 7 and including means for producing an electron lens at each aperture for concentrating and directing electrons emitted by elemental areas of said photoemissive layer in registry with said apertures respectively onto elemental areas of said phosphor which are also in registry with said apertures respectively.

9. An image intensifier comprising an evacuated envelope, first and second planar transparent supporting plates mounted in said envelope, said plates being parallel and in proximity to each other, the inner facing surfaces of said plates being parallel, a layer of photoelectric material on the inner surface of said first plate, a layer of transparent phosphor material on the inner surface of said second plate, a planar anode element of predetermined thickness interposed between said plates, said element having a plurality of apertures through which electrons and light pass between said facing surfaces, the outer surface of said second plate being divided into a plurality of spherically curved surfaces, said spherical surfaces being in registry with said apertures, respectively, a layer of light-reflective material on said other surface, the light-reflective material on each spherical surface providing a mirror having a focal point in the plane of said phosphor layer, and viewing apertures in the reflective material, there being one viewing aperture for each spherical surface, and a pulse generator coupled between said photoelectric and phosphor layers, said pulse generator applying to said layers repetitive pulses of unidirectional voltage of sufficient magnitude to excite said phosphor, each said pulse having a duration less than that required to drive said phosphor to saturation brightness.

10. An image intensifier having a photoelectric and a phosphor layer facing each other in parallel position; electron-optical means arranged between them to subdivide the electron flow into a plurality of adjacent channels; optical means to prevent light emitted from the phosphor toward the cathode from passing through adjacent channels, and optical-reflecting means to direct the light from the phosphor back toward the cathode element in the same channel.

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