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N. T. MELAMED ET AL
IMAGE REPRODUCTION SYSTEM

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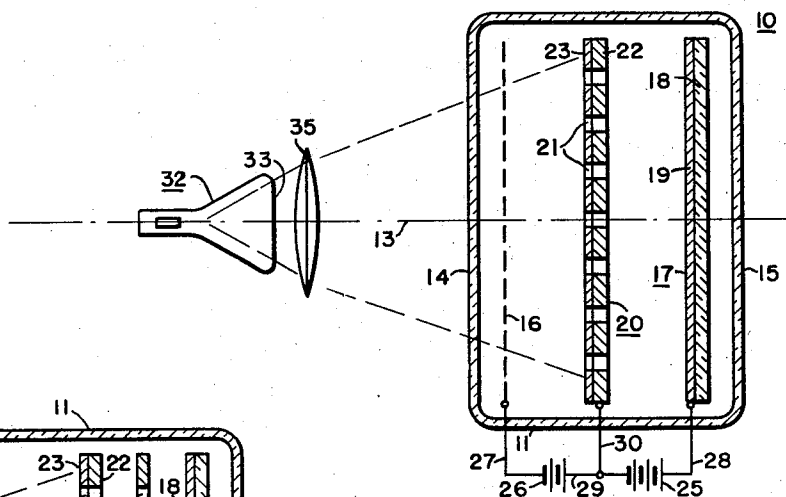


Fig. 1.

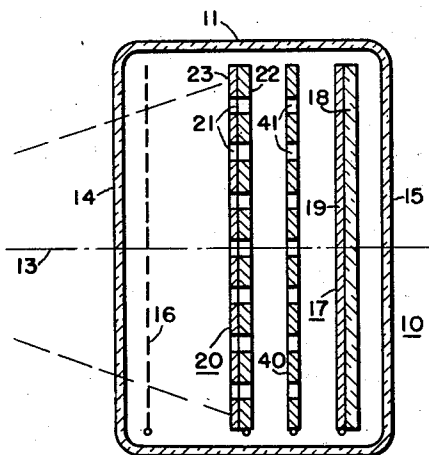


Fig. 2.

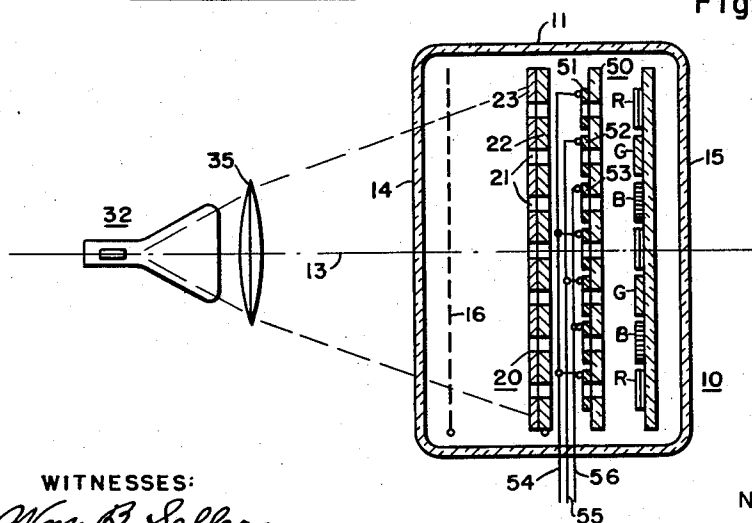


Fig. 3.

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1

2,888,513

IMAGE REPRODUCTION SYSTEM

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9 Claims. (Cl. 178—5.4)

This invention relates to image reproduction systems, and more particularly to image intensifying devices.

It is an object of this invention to provide a new and improved image intensifying system.

It is another object to provide an image intensifying system for utilization in projection television systems.

It is another object to provide an image reproduction system to present an image having uniform brightness over all viewing angles.

It is another object to provide an image intensifier requiring relatively low voltages.

These and other objects are effected by this invention as will be apparent from the following description taken in accordance with the accompanying drawing throughout which like reference characters indicate like parts, and in which:

Figure 1 shows a preferred embodiment of our invention;

Fig. 2 shows a modification of the image intensifier shown in Fig. 1; and

Fig. 3 shows a further modification of the image intensifier shown in Fig. 1 for presentation of a color image.

Referring in detail to Fig. 1, the image intensifier device comprises an evacuated envelope 10. One example of an envelope 10 is a cylindrical body 11 and two end plates 14 and 15 closing off the ends of the cylindrical body 11. The end plates 14 and 15 are made of a suitable transparent optical glass through which light rays may pass undistorted. At one end of the envelope 10 near the end plate 14, a large area electron emissive electrode 16 is positioned. The electron emissive electrode or cathode 16 is sufficiently large to be capable of supplying any given cross sectional area within the cylindrical member 11 with an electron stream having substantially the same electron density over the entire cross sectional area. The cathode 16 may be of any suitable type such as in the form of a grid-like filament structure of very fine wire. In the specific embodiment shown, it is necessary that the cathode 16 also be capable of transmitting substantially all the light projected through the end plate 14 of the envelope 10.

Positioned near the opposite end of the envelope 10 near the end plate 15, there is an image screen 17. The image screen 17 is of substantially the same area as the end plate 15 and is perpendicular to the axis 13 of the envelope 10. The image screen 17 is substantially parallel to the end plate 15. The image screen 17 is comprised of a supporting conductive transparent structure 18 of a material such as glass coated with conductive layer 19 of a material such as tin oxide with a phosphor coating 19 on the surface thereof facing the cathode 16. The image screen 17 may also be made by depositing a transparent conductive layer such as tin oxide on the interior surface of the end plate 15 and then depositing the phosphor material on the exposed surface of the conductive layer of tin oxide. Another possible structure of the image screen 17 is to deposit the phosphor material directly onto the interior surface of the end plate 15 and then

2

apply a coating of a suitable conductive material such as aluminum on the exposed surface of the phosphor material. The conductive coating is made sufficiently thin so as to be substantially permeable to electrons.

The phosphor material utilized in the layer 19 of the image screen 17 is capable of emission of light of substantially a white color and an example for television projecting is a mixture of zinc sulfide activated by silver and zinc-cadmium sulfide activated by silver.

Positioned intermediate of the cathode 16 and the image screen 17 is a storage grid structure 20. The grid 20 is substantially of the same area as the image screen 17 and is also perpendicular to the axis 13. The grid 20 is a perforated member having a plurality of apertures 21 spaced therein in a desired pattern. The grid 20 is comprised of a layer 22 of a conductive material and which may also serve as the supporting structure of the grid 20. A photoconductive layer 23 is deposited on the surface of the conductive member 22.

The conductive member 22 may be of a perforated metal sheet of sufficient thickness to be self-supporting as described in the specific embodiment, or a perforated glass support member with a conductive coating such as tin oxide thereon or a woven wire mesh may be utilized.

The photoconductive material utilized in the layer 23 should be of appropriate decay characteristics and will be defined later for the specific embodiment shown in the drawing.

In the specific embodiment shown in Fig. 1, a suitable photoconductive material is antimony trisulfide which is applicable for use in a device for intensification of a light image. If the device is to be utilized as an X-ray intensifier, a suitable photoconductive material would be cadmium sulfide, while for infrared, a compound such as lead tellurium could be employed.

The resolution of the device shown in Fig. 1 is essentially limited by the size and spacing of the apertures 21 within the grid 20.

A suitable potential of about 5000 volts is supplied between the cathode 16 and the image screen 17 by means of suitable voltage sources represented by the batteries 25 and 26 which are connected in series. A lead 27 is supplied from the interior of the envelope 10 for connecting the cathode 16 to the negative terminal of the battery 26. A lead 28 is provided from the interior of the envelope 10 which is connected to the conductive layer 18 of the image screen 17 and is in turn connected to the positive terminal of the battery 25. The positive terminal of the battery 26 is connected to the negative terminal of the battery 25 by means of a conductor 29. A lead 30 is provided from the interior of the envelope 10 which is connected to the conductive member 22 of the control grid 20 to the conductor 29 to provide a suitable bias between the cathode 26 and the grid 20. A positive bias is applied to the grid 20 with respect to the cathode 16 so as to obtain the maximum range of control with the grid 20.

The light image to be intensified by the device shown in Fig. 1 is projected onto the photoconductive layer 23 of the grid 20. In the specific embodiment shown in Fig. 1, a television image is received on a suitable projection type kinescope 32 of suitable design and by means well known in the art. The light image developed on the screen 33 of the kinescope 32 is projected by suitable optical means 35 onto the photoconductive layer 23 of the control grid 20.

In the operation of the device shown in Fig. 1, a stream of electrons of substantial cross sectional area substantially equal to the cross sectional area of the cylindrical member 11 and having substantially uniform intensity over the entire cross sectional area is provided by the cathode 16. When voltage is first applied to the

3

tube, the grid 20 will be at a positive potential with respect to the cathode 16 due to the battery 26. At this first instance of tube starting, a small burst of electrons will pass through the apertures 21 of the grid 20 and then be accelerated onto the image screen 17 by the voltage impressed between the grid 20 and the image screen 17 by the battery 25. After this first burst of electrons, the tube will reach a stable or normal state of operation wherein the grid 20 will effectively cut off any electron current flowing between the cathode 16 and the image screen 17. This effective cutoff potential on the grid 20 is obtained by a substantially equal uniform negative charge built up over the entire surface of the photoconductive layer 23. This uniform charge on the surface of the photoconductive layer 23 is obtained by the attraction of electrons by the positive voltage on the grid 20 with respect to the cathode 16. The light image which is in effect a modulated light spot obtained from the screen 33 of the kinescope 32 which is to be intensified is now projected by the lens means 35 onto the photoconductive layer 23. The result of the illumination from the kinescope 33 upon the photoconductive layer 23 is to decrease the resistance of elemental areas (equivalent to the size of the light spot) of the photoconductive layer 23 in proportion to the quantity of light impinging thereon. The reduction of resistance of the photoconductive layer 23 allows the accumulated electron charge on the surface of the photoconductive layer 23 to pass through the photoconductive layer 23 to the conductive layer 22. This in effect modulates or modifies the uniform charge distribution on the surface of the photoconductive layer 23 from the cutoff condition so as to reduce the negative charge on elemental areas of the surface of the photoconductive layer 23 and thereby permit electrons from the cathode 16 to pass through the apertures 21 in the grid 20 in amounts determined by the reduction in charge surrounding the respective apertures 21.

The scanned charge image obtained on the surface of the photoconductive layer 23 due to the impingement of the light image thereon forms an electron image leaving the grid 20 through the apertures 21 and moving toward the image screen 17. The electron image leaving the grid 20 is accelerated to the image screen 17 by the potential of the battery 25 across the image screen 17 and the grid 20. The electron image on striking the phosphor layer 19 is converted into a light image representative of the light image projected onto the photoconductive layer 23 from the tube 32.

The light from the kinescope 32 projected onto the grid 20 acts in effect to gate the grid 20 in an amount of which is determined by the quantity of light falling thereon.

In the use of kinescopes, the light image on the screen 33 is obtained by scanning so that only one elemental area or picture element is excited at a given time and for a length of time corresponding to the time the electron beam within the kinescope 32 rests on one element of the screen 33.

By utilizing a photoconductive material of appropriate decay characteristics, each elemental area on the grid 20 can remain open for an appreciable portion of the frame time causing each corresponding phosphor area on the screen 17 to remain exposed to the excitation from the electron beam obtained from the cathode 16 for a much longer time than in a conventional kinescope. This in effect gives an increase in overall brightness of the image obtained on the image screen 17 and is over and above the inherent gain of the conventional image intensifier.

The electron emissive cathode 16 may also consist of a large area photoemissive material, such as the alkali metals, or cesium antimonide (all well known in the art of vacuum phototubes), applied directly to the interior face of end plate 14, or on a transparent conducting

4

coating such as tin oxide applied to the interior surface of the end plate 14.

The photoemissive material can be caused to discharge a continuous stream of electrons by irradiating it with radiation, such as ultraviolet light from an external source. The photoemissive layer should be sufficiently thin, however, to transmit a substantial portion of the image to be amplified, for example, the image on screen 33, and should be relatively unaffected by the image radiation. Thus, to amplify an image composed of visible radiation, the photoemissive cathode might be made sensitive to ultraviolet light but insensitive to visible radiation, and having a minimal absorption for the visible radiation.

The use of a photoemissive cathode such as described above may require a lower power consumption than a heated filament cathode. In addition, it permits the device to be used in another important manner. Supposing, for example, it is desired to intensify a weak infrared image, which is projected on a screen, by means of, say, a lantern slide projector. The image is a total image (not one produced by scanning) which is projected on grid 20 by suitable optics. A photoconductive material sensitive only to infrared would be utilized as the layer 23. If it is desired now to scan this projected image, it could be done by using a photoemissive cathode which was not sensitive to infrared but was sensitive to, say, visible or ultraviolet and to excite this cathode using a scanning light spot, produced by a cathode ray tube containing a uniform raster. In this way, a scanning electron beam would be produced which would be permitted to pass through the apertures in proportion to the amount of infrared illumination at each aperture.

Referring in detail to Fig. 2, there is shown a similar device to that shown in Fig. 1 except for the modification in the material utilized in the photoconductive layer 23 of the grid 20 and the insertion of a second or video grid between the grid 20 and the image screen 17. The light source utilized for scanning the photoconductive layer in a device such as shown in Fig. 1 is again a kinescope 32, but instead of utilizing the televised image or modulated light spot, a blank raster or an unmodulated scanning light source is utilized. The video intelligence is introduced into the intensifier by means of a grid 40.

The video grid 40 is of a conductive material and is substantially parallel to the grid 20 and of similar cross sectional area. A plurality of apertures 41 are positioned within the grid 40 as to be in substantial electron registry with the apertures 21 in the grid 20. The grid 40 may be of a perforated metal sheet as illustrated in the specific embodiment shown in Fig. 2 or may be of a glass supporting structure with a conducting layer deposited thereon or may be simply of a woven wire mesh.

The operation of the device shown in Fig. 2 is similar to that described with reference to Fig. 1 except that a light spot of uniform intensity is utilized for scanning point by point across the photoconductive layer 23 and the video modulation is not impressed upon the scanning light spot. The effect of the light spot scan is to simply gate the control grid either on or off point by point in the scanning raster. The video signal obtained from a suitable television receiver (not shown) is applied to the grid 40 and modulates or controls the amount of electrons passing through the apertures therein. The video signals applied to the grid 40 are synchronized with the position of the scanning light spot of the kinescope 32 so that an image will be reproduced on the image screen 17 of intensified brightness representative of the video signal applied to the grid 40.

In Fig. 3 we have made a further modification of the device shown in Fig. 2 in that we now are able to present an image in natural color. This necessitates the modification of the phosphor coating 19 so that a plurality

5

of elemental areas represented of the selected component colors are deposited thereon. In our specific embodiment, we have utilized a plurality of horizontal strips R, G and B of phosphor material arranged in groups and comprised of three phosphor strips R, G and B representative of the red color R, the green color G and the blue color B. Suitable phosphor materials for the presentation of the desired colors are for blue, zinc sulfide activated by silver, for green, zinc orthosilicate activated by manganese and for red, zinc phosphate activated by manganese. The video grid 40 in Fig. 2 is also modified and in its place a video grid 50 comprised of a plurality of horizontal elements 51, 52 and 53 aligned with the respective phosphor strips R, G and B and having apertures therein which are in substantial registry with the apertures 21 in the grid 20. The conductive elements 51, 52 and 53 of the video grid 50 are insulated from each other and those elements having the same number which are also positioned in front of like phosphor strips are connected together by suitable means so that three leads 54, 55 and 56 are brought out external to the envelope 10 onto which the color video information representative of the three selected component colors is applied in a manner such as described in a copending application entitled "Color Television Tube," by A. P. Kruper and C. H. Jones, Serial No. 411,382, filed February 19, 1954, and assigned to the same assignee as the present invention.

The operation of the device shown in Fig. 3 is similar to that described with reference to Fig. 2 in that a blank raster is scanned by a light spot obtained from the kinescope 32 in a horizontal line across the control grid 20 to effectively gate the control grid 20 on or off dependent upon the position of the light spot. The video intelligence which is applied to the respective conductive elements 51, 52 and 53 of the video grid 50 is synchronized with the scanning light spot obtained from the kinescope 32 so that the electron image leaving the video grid 50 is representative of the color image received by a suitable receiver (not shown). The electron image leaving the grid 50 is converted into a light image on striking the correct phosphor strips R, G and B.

While we have shown our invention in several forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit and scope thereof.

We claim as our invention:

1. An image intensifier comprising an envelope having therein an electron emissive surface at one end of said envelope to produce a flooding stream of electrons, an electron sensitive surface positioned at the opposite end of said envelope, an apertured grid member positioned intermediate of said electron emissive surface and said electron sensitive surface, said grid member comprising a supporting member having a conductive layer on the surface thereof facing said electron emissive surface, a photoconductive layer on the exposed surface of said conductive layer, and means for projecting radiations from an object or field of view upon said photoconductive layer.

2. An image intensifier comprising an envelope and having therein an electron emissive surface at one end of said envelope to produce a stream of electrons of substantially uniform intensity over the entire surface, a luminescent screen positioned at the opposite end of said envelope, an apertured grid member positioned intermediate of said electron emissive surface and said luminescent screen, said grid member comprised of a conductive supporting member having a photoconductive layer on the surface thereof facing said electron emissive surface, and means for projecting radiations from an object or field of view upon said photoconductive layer.

3. An image intensifier comprising an envelope and having therein a large area cathode for producing a

6

stream of electrons of substantially uniform intensity over the surface thereof, a light reproducing screen positioned at the opposite end of the envelope, an apertured first grid member positioned intermediate of said cathode and said light producing screen, said first grid member comprising a supporting conductive member and a photoconductive layer on the surface of said conductive supporting member facing said cathode, a second grid member positioned between said first grid member and said light reproducing screen comprising a conductive electrode having substantially the same area as said first grid and comprised of a conductive member having a plurality of apertures therein in substantial electron registry with the apertures in said first grid member, means for projecting a scanning light beam upon said photoconductive layer, means for applying to said second grid video intelligence synchronized with said scanning light beam so as to produce an electron image representative of the video intelligence applied to said second grid and means for accelerating said electron image to said light-reproducing screen so as to form a light image.

4. An image intensifier comprising an envelope and having therein a cathode at one end of said envelope to produce a flooding stream of electrons, a luminescent screen positioned at the opposite end of said envelope, an apertured grid member positioned intermediate of said cathode and said luminescent screen, said grid member comprised of a supporting conductive member and a photoconductive layer positioned on the side of said supporting conductive member facing said cathode, means for applying a voltage to said grid member with respect to said cathode so that a charge will be built up on the surface of said photoconductive layer so as to cut off electron flow between said cathode and said luminescent screen, and means for projecting radiations from an object or field of view upon said photoconductive layer so as to modulate the charge on the surface of said photoconductive layer and thereby produce an electron image between said grid and said luminescent screen representative of said object or field of view.

5. An image intensifier comprising an envelope and having therein a planar cathode to produce substantially uniform electron intensity over the entire area of said cathode, a phosphor screen positioned at the opposite end of said envelope, an apertured grid member positioned between said cathode and said phosphor screen, said grid member comprised of a conductive member of substantially the same area as said cathode and said phosphor screen and transverse to the electron stream from said cathode, said conductive member having a layer exhibiting the property of increased conductivity in response to electromagnetic radiation and adapted to assume an electrical charge from the electrons from said cathode so as to cut off electron flow between said cathode and said phosphor screen, means for projecting radiation onto said radiation responsive layer so as to modify the charge on said radiation responsive layer to modulate the stream of electrons from said cathode to said screen in accordance with the charge image on said radiation responsive layer representative of the radiation image projected thereon.

6. An image reproduction system comprising an image intensifier tube comprising an envelope and having therein a planar cathode to produce an electron stream having substantially uniform intensity over the entire cross-sectional area of said planar cathode, an image screen positioned at the opposite end of said envelope and having a plurality of elementary areas of phosphor materials representative of selected component colors, a first apertured electron control grid positioned between said cathode and said image screen of substantially the same area as said cathode and positioned transverse to said electron stream, said first electron control grid comprised of a conductive layer having a photoconductive layer on the surface thereof facing said cathode and adapted to assume an electri-

cal charge from the flooding electrons from said cathode so as to cut off electron flow between said cathode and said image screen, means for projecting a scanning light spot onto said photoconductive layer so as to modulate streams of electrons through said apertures in said electron control grid in accordance with the charge thereon, a second video control grid positioned between said first electron control grid and said image screen comprising a plurality of insulated elemental apertured conductive areas, means for applying video intelligence to said first video grid and to those selected conductive areas which are in substantial electron registry with selected phosphor areas of said phosphor screen.

7. A color television projection system comprising an image intensifier comprising an envelope having therein means for producing a stream of electrons of substantial uniform intensity over the entire cross sectional area, an image screen positioned at the opposite end of said envelope with respect to said electron stream light producing means comprising a plurality of horizontal groups of strips of phosphor material capable of emitting light of a color individual to that strip, each of said groups having phosphor strips capable of producing light representative of each of the selected component colors upon electron bombardment, an apertured first grid member positioned intermediate of said electron stream producing means and said image screen, said first grid member comprised of a supporting conductive member of substantially the same area as said electron stream producing means and having a photoconductive layer on the surface of said conductive member facing said electron stream producing means, said photoconductive layer adapted to assume a negative electrical charge from said stream of electrons so as to effectively cut off any electron flow between said electron stream producing means and said image screen, means for projecting a light image on said photoconductive layer so as to modulate the charged density on said photoconductive layer to permit electron flow through said first grid in response to the quantity of light thereon, a second apertured grid member comprising a plurality of vertical insulated elementary apertured conductive elements, means for applying video intelligence representative of the selected component colors to selected elements of said second grid so as to control the quantity of electrons within said electron streams passing between said first grid and said image screen so as to produce an image in natural color on said image screen.

8. A color image reproducing device comprising in combination, an envelope having therein a first foraminous grid of substantial area having a photoconductive charge storage surface on one side thereof, an electron

gun positioned on the side of said first foraminous grid facing said photoconductive charge storage surface for generating a low velocity flooding electron beam of substantial cross sectional area at said first foraminous grid, an image screen positioned on the opposite side of said first foraminous grid with respect to said electron gun, said image screen having a plurality of elemental areas of phosphor representative of selected component colors, means for controlling the flow of electrons to each of the elemental areas of phosphor on said image screen, comprising a second foraminous grid positioned between said first foraminous grid and said image screen, said second foraminous grid consisting of a plurality of elemental control areas in substantial registry with elemental phosphor areas on said image screen, and means for controlling the flow of electrons through each of the elemental conductive areas of said second grid to the corresponding elemental area of said image screen by varying the potential applied thereto to construct an intelligence image on said image screen.

9. An image reproducing device comprising in combination, a first foraminous grid of substantial cross area positioned near the intermediate point of said envelope, said first foraminous grid having a photoconductive charge storage surface on one side thereof, an electron gun for generating a relatively low velocity flooding electron beam of cross sectional area substantially the same as said first foraminous grid, an image screen positioned on the opposite side of said first foraminous grid with respect to said electron gun, means for developing a scanning light raster on said photoconductive layer of said first foraminous grid to control the flow of electrons through elemental areas of said first foraminous grid so as to scan a blank raster thereon, and means comprising a second foraminous grid with a voltage applied thereto so as to construct an intelligence image on said image screen.

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