Sept. 26, 1961 A. E. ANDERSON ET AL 3,002,101

IMAGE AMPLIFIER

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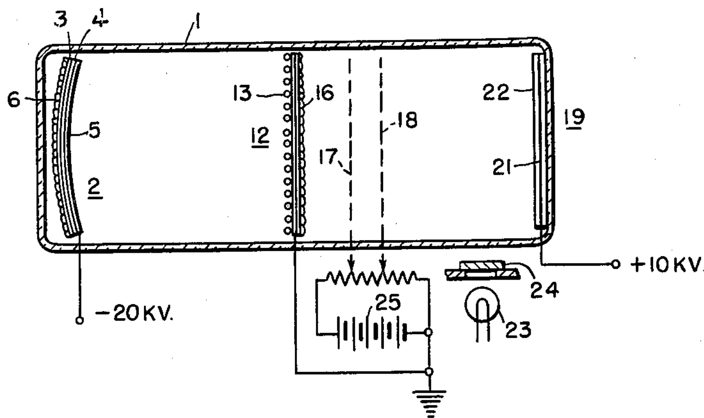
Fig. 1.



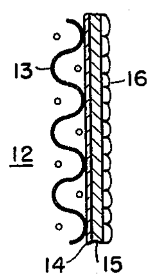
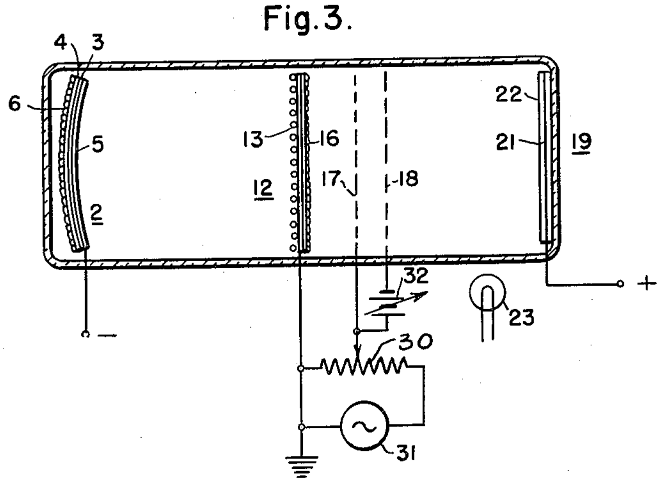




Fig. 2.

Fig. 3.

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# IMAGE AMPLIFIER

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Our invention relates to X-ray image intensifying devices and, in particular, relates to a single tube which is adapted to receive a single X-ray image on its fluorescent input screen and to produce on its output screen a replica thereof in output rays which is increased in brightness by many thousand fold while maintaining the diameter of the output image sufficiently large to permit viewing through a large exit pupil. Our invention is an improvement upon the X-ray image intensifier described in Mason and Coltman's U.S. Patent 2,523,132 issued about September 19, 1950, for Photosensitive Apparatus.

In the attainment of brightness intensification of the above-mentioned degree without such contraction in size of the image on the output screen relative to that on the input screen as to make binocular viewing of the output image with a large exit pupil impracticable we achieve our brightness intensification by utilizing the amplifying properties inherent in the phenomenon known as electron-bombardment-induced electrical conductivity.

One object of our invention is accordingly to provide a new and improved form of image intensifier.

Another object is to provide a new and improved form of integral tube producing on an output screen a light image which is a replica of greatly enhanced brightness of an image on its input screen.

Another object is to provide a single integral tube of improved form for producing on its output screen an intensified image, without such reduction in image size as to make binocular viewing of the output image through a large exit pupil impracticable.

Still another object is to provide, in an integral image intensifier tube, means by which the contrast between shadowgraphs of only slightly different intensity-level may be selectively varied at will whereby the images of certain objects or organs may be brought out clearly while other image-portions are suppressed into background.

Other objects of our invention will be made apparent by reading the following description taken in connection with the attached drawings in which:

FIGURE 1 is a schematic view in section of a tube embodying the principles of our invention;

FIG. 2 is a schematic cross-section of a target screen employed in FIG. 1;

FIG. 3 is a schematic diagram of a circuit and ancillary structure for operating the tube of FIG. 1 in a modified way.

Referring in detail to FIG. 1, a vacuum-tight enclosure 1, which may if desired be of glass, has a cathode screen 2 near one end which may comprise a thin glass wall 3 coated on its inner (concave) face with a thin layer of transparent conducting material 4 on which is deposited a photo-emissive material such as cesiated antimony 5. The outer (convex) face of glass wall 3 is coated with a layer 6 of fluorescent material such as zinc-cadmium sul-



phide. When an X-ray field is projected onto layer 6 through the wall of enclosure 1, the light generated therein is transmitted through glass wall 3 and conductive layer 4 and generates at the surface of photo-emissive layer 5 an electron image which is a replica of the X-ray field or picture incident on layer 6. An electron lens system (not shown) focusses a contracted replica of this electron image on a target 12 which is shown in section in FIG. 2. The target 12 comprises a screen of metal wire 13 having a large ratio of open space to solid area supporting a layer 14 of aluminum thin enough to be substantially transparent to the electrons focussed on it by the electron lens system aforesaid. The other face of the aluminum layer 14 is coated with a thin layer 15 of an insulating dielectric such as arsenic trisulphide which is briefly rendered substantially conductive across its thickness where an electron (passing through the aluminum layer 14) has penetrated. The free surface of the insulating layer 15 is covered with a mosaic of photoemissive material 16 such as cesiated antimony.

Spaced by a small distance from the mosaic layer 16 is a first grid 17, and spaced by a similar distance from grid 17 is a second grid 18. An output screen 19 comprising an electron phosphor layer 21 coated on the side facing grid 18 with a coating 22 of aluminum thin enough to transmit electrons propelled toward it from mosaic 16. The electron phosphor 21 may be zinc-cadmium sulphide, for example, and may be supported on the inner face of the end wall of enclosure 1. The photoemissive layer 5, the aluminum layer 14, the grids 17 and 18, and the aluminum coating 22 are provided with leads by which their electrical potentials may be fixed at will by suitable voltage sources (not shown); for example photoemissive layer 5 may be made negative relative to aluminum layer 14 by twenty kilovolts, grid 17 positive to layer 14 by fifty to one hundred volts, and aluminum coating 22 positive thereto by about five kilovolts. A light source 23 uniformly illuminates mosaic 16 through a shutter 24.

In the simplest mode of operation, in which grid 18 may be absent or be connected to grid 17 and in which light source 23 continuously illuminates mosaic 16, the X-ray field incident on fluorescent layer 6 generates at the face of photoemissive layer 5 an electron image corresponding in intensity distribution to the X-ray field. This electron image is accelerated by the voltage between layers 5 and 14 into impact which penetrates the latter and sets up in resistance layer 15 a distribution of electrical conductivity, which may be thought of as a conductivity image which is a replica of the original X-ray field incident on layer 6. The light field from source 23 causes the various islands of the mosaic 16 to emit electrons, but the conductivity image in layer 15 determines the rate of this emission from island to island over the area of the mosaic. A fractional part of those emitted electrons miss the wires of grid 17 and are attracted into incidence with the aluminum layer 22 which they penetrate and excite luminescence in electron-phosphor layer 21. Any suitable means such as an axial magnetic field may, of course, be provided for focussing the electron images on target screen 12 and output screen 19. Such an arrangement may be made to produce a light image on output screen 19 which is several thousand times as bright as the fluorescent light image generated in the input layer 6. It does not, however, permit reduction in the average brightness of the output images without proportional reduction of the small brightness variations which are often found to be superposed on a large background in fluoroscopic images. The mode of operation now to be described makes this possible, however.

In this second mode of operation reduction of background without loss of detail brightness variations is effected by velocity selection of electrons emitted from mosaic 16 when illuminated with pulsed or intermittent light from source 23. Shutter 24 alternately cuts on and cuts off incidence of light from source 23 on mosaic 16. During each on-period all islands of mosaic 16 are charged to the potential of grid 17. Then the light from source 23 is cut off and the respective islands of mosaic 16 discharge at a rate determined by the conductivity image in resistance-layer 15. When shutter 24 again permits light from source 23 to strike the mosaic 16 the electron emission from the respective islands will equal the number discharged during the preceding dark interval, and the electrons emitted from the respective islands are accelerated into impact with a point of corresponding position on the output screen 19. The net electron gain at each island corresponds to the ratio of conduction electrons to electrons bombarding its position on resistance layer 15, and this ratio may be one hundred or more to one at room temperature, and increases as temperature of layer 15 is raised. Where, as here described, the potential difference from mosaic 16 to grid 17 is small, the spacing between them should, in order to maintain image resolution, be small, and/or an axial magnetic field be employed to preserve definition. Thus a solenoid energized by continuous current and coaxial with the tube 1 might be provided for this purpose. By impressing grid 18 with a potential which is a few volts negative relative to grid 17 background brightness may be eliminated and an increase in contrast accomplished. The pulse rate of shutter 24 should be sufficiently high to prevent annoying flicker in the image on output screen 19. Also, by a proper choice of the interval T between light pulses in relation to $\rho\epsilon$ of the layer 15, one may influence the contrast quality of the output image in a manner such as to enhance selectively the contrast at a desired brightness level, since the time constant of the discharge of the mosaic elements is proportional to the resistivity and dielectric constant of the resistance layer 15 at the respective brightness levels.

By varying the potential of grid 18 the minimum brightness level in the image at output screen 22 may be varied at will, and the level at which greatest contrast between image shades occurs be fixed at will. This achieves the very important result that a desired object or organ may be made to stand out clearly on the screen 21 while undesird organs fade into the background. This result is effected within the confines of a single tube.

FIG. 3 illustrates a modified form of our invention in which the direct current voltage source 25 is replaced by an alternating voltage source 31 of the order of fifty volts including adjustable resistor 30, and the shutter 24 is omitted. Since the FIG. 3 arrangement is otherwise like FIG. 1, further detailed description of its structure is believed to be unnecessary. In this arrangement the islands of mosaic 16 emit electrons while the voltage of source 31 is above a certain threshold (as those of FIG. 1 do when light from source 23 is turned on), and the respective islands receive electrons (i.e. they discharge) in accordance with the conductivity image in resistance layer 15 when the voltage of source 31 is below the threshold (just as the islands of FIG. 1 do when light from source 23 is cut off). During that portion of every cycle of source 31, when the voltage of grid 17 is above its threshold, the electrons emitted from the respective islands of mosaic 16 are accelerated into incidence with output screen 19. An adjustable direct current source 32 keeps grid 18 a few volts negative to grid 17 and so makes it possible to cut down background brightness and effectively increase contrast in the image on screen 19 at any desired shade-level.



In both the FIG. 1 and the FIG. 3 arrangements it may be desirable to heat the resistance layer 15 to operate at a temperature giving the greatest conductivity change per bombarding electron. Furthermore, the photo-emissive islands of the mosaic 16 may be replaced by thermionically-emissive islands heated to their most desirable operating temperature by an electrical or radiation heater properly positioned. The same heater may in fact be made to perform both these heating functions. Thermionic emission might permit the use of temperatures for resistance layer 15 that would be ruinous to photo-emissive islands if layer 16 were made up of the latter. Barium-strontium-oxide emitters operating at five hundred degrees Kelvin will emit 10 microamperes per square centimeter, and such a temperature is desirable for certain insulation layers 15. The layer 15 may be very thin, as a result of which picture areas of very small size, i.e. of a diameter about equal to the film thickness, can be satisfactorily resolved. Even very thin films have both a high gain and a high resolution. Thicknesses from one micron up have proven entirely satisfactory.

By omitting the fluorescent layer 6, the arrangements of each figure may be applied to intensification of ordinary light images; for example, those focused on the input screens of television pickup tubes; and the use of materials for layer 6 which emit light images on receipt of other radiations than X-rays is also within the contemplation of our invention.

While we have described the layer 15 as of arsenic trisulphide, other materials which exhibit the property of electron-bombardment-conductivity may be used; selenium, cadmium sulphide and anthracene may be mentioned as examples.

We claim as our invention:

1. In combination with a vacuum-tight container, an input screen of transparent material having a fluorescent coating on one side and a photoelectrically-emissive surface on its other side, a target screen having a layer of material which has the property of electron-bombardment-induced-conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen, and a mosaic of islands having photoelectrically-emissive surfaces on the side of said electron-bombardment-induced conductivity layer remote from said input screen, photo-means for irradiating said mosaic of islands to cause electron emission from their surfaces, an output screen comprising an electron phosphor, a grid electrode between said mosaic of islands and said output screen, and inleads for impressing potential differences between said target and said input screen, and between said output screen and said grid electrode, said photo-means for irradiating operates intermittently.

2. In combination with a vacuum-tight container, an input screen comprised of a transparent support member having a fluorescent coating on one side and a photoelectrically emissive surface on its other side, a target screen comprising a layer of material which has the property of electron-bombardment-induced conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen and a mosaic of islands having photoelectrically emissive surfaces on the side of said electron-bombardment-induced conductivity layer remote from said input screen, means for irradiating said islands to cause electron emission from their surfaces, an output screen positioned on the opposite side of said target with respect to said input screen comprising a layer of electron sensitive material, a first grid electrode positioned between said target and said output screen, a second grid electrode positioned between said first grid electrode and said output screen, and means for impressing potential

differences respectively between said target, said input screen, said output screen and said grid electrode.

3. In combination with a vacuum-tight container, an input screen comprised of a transparent support member having a fluorescent coating on one side and a photoelectrically emissive surface on its other side, a target screen comprising a layer of material which has the property of electron-bombardment-induced conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen and a mosaic of islands having photoelectrically emissive surfaces on the side of the mosaic remote from the input screen on the side of said electron-bombardment-induced conductivity layer remote from said input screen, means for irradiating said islands to cause electron emission from their surfaces, an output screen positioned on the opposite side of said target with respect to said input screen comprising a layer of electron sensitive material, a first grid electrode positioned between said target and said output screen, a second grid electrode positioned between said first grid electrode and said output screen, and means for impressing potential differences respectively between said target, said input screen, said output screen and said grid electrode.

4. In combination with a vacuum-tight container, an input screen comprised of a transparent support member having a fluorescent coating on one side and a photoelectrically emissive surface on its other side, a target screen comprising a layer of material which has the property of electron-bombardment-induced conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen and a mosaic of islands having photoelectrically emissive surfaces on the side of the mosaic remote from the input screen on the side of said electron-bombardment-induced conductivity layer remote from said input screen, means for irradiating said islands to cause electron emission from their surfaces, an output screen positioned on the opposite side of said target with respect to said input screen comprising a layer of electron sensitive material, a first grid electrode positioned between said target and said output screen, a second grid electrode positioned between said first grid electrode and said output screen, and means for impressing potential differences respectively between said target, said input screen, said output screen and said grid electrode, said irradiating means operating intermittently.

5. In combination with a vacuum-tight container, an input screen comprised of a transparent support member having a fluorescent coating on one side and a photoelectrically emissive surface on its other side, a target screen comprising a layer of material which has the property of electron-bombardment-induced conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen and a photoemissive layer on its side remote from said input screen on the side of said electron-bombardment-induced conductivity layer remote from said bombardment-induced conductivity layer remote from said input screen, means for irradiating said photoemissive layer to cause electron emission from their surfaces, an output screen positioned on the opposite side of said target with respect to said input screen comprising a layer of electron sensitive material, a first grid electrode positioned between said target and said output screen, a second grid electrode positioned between said first grid electrode and said output screen, and means for impressing potential differences respectively between said target, said input screen, said output screen and said grid electrode.

6. In combination with a vacuum-tight container, an input screen comprised of a transparent support member having a fluorescent coating on one side and a photoelectrically emissive surface on its other side, a target screen comprising a layer of material which has the



property of electron-bombardment-induced conductivity, an electrical conductive layer on the surface of said electron-bombardment-induced conductivity layer facing said input screen and an electron emissive layer on its side remote from said input screen on the side of said electron-bombardment-induced conductivity layer remote from said input screen, means for exciting said electron emissive layer to cause electron emission from their surfaces, an output screen positioned on the opposite side of said target with respect to said input screen comprising a layer of electron sensitive material, a first grid electrode positioned between said target and said output screen, a second grid electrode positioned between said first grid electrode and said output screen, and means for impressing potential differences respectively between said target, said input screen, said output screen and said grid electrode.

7. In combination with image means for creating a conductvity-image in a layer of material exhibiting the property of electron-bombardment-induced conductivity, a conductive first layer adjacent one face of said layer, a photoelectrically-emissive second layer on the other face of said layer, an electron-receiving screen spaced from said second layer, a first grid electrode and a second grid electrode serially positioned between said second laye rand said electron-receiving screen, circuit means to impress a first potential difference between said first grid electrode and said layer of electron-bombardment-induced conductivity material and a second potential difference between said first grid electrode and said second grid electrode.

8. In combination with image means for creating a conductivity-image in a layer of material exhibiting the property of electron-bombardment-induced conductivity, a conductive first layer adjacent one face of said layer, a photoelectrically-emissive second layer on the other face of said layer, an electron-receiving screen spaced from said second layer, a first grid electrode and a second grid electrode serially positioned between said second layer and said electron-receiving screen, circuit means to impress a first potential difference between said first grid electrode and said layer of electron-bombardment-induced conductivity material and a second potential difference between said first grid electrode and said second grid electrode in which said second potential difference is adjustable.

9. In combination with image means for creating a conductivity-image in a layer of material exhibiting the property of electron-bombardment-induced conductivity, a conductive first layer adjacent one face of said layer, a photoelectrically-emissive second layer on the other face of said layer, an electron-receiving screen spaced from said second layer, a first grid electrode and a second grid electrode serially positioned between said second layer and said electron-receiving screen, circuit means to impress a first potential difference between said first grid electrode and said layer of electron-bombardment-induced conductivity material and a second potential difference between said first grid electrode and said second grid electrode in which said first potential difference is pulsating.

10. In combination with image means for creating a conductivity-image in a layer of material exhibiting the property of electron-bombardment-induced conductivity, a conductive first layer adjacent one face of said layer, a photoelectrically-emissive second layer on the other face of said layer, an electron-receiving screen spaced from said second layer, a first grid electrode and a second grid electrode serially positioned between said second layer and said electron-receiving screen, circuit means to impress a first potential difference between said first grid electrode and said layer of electron-bombardment-induced conductivity material and a second potential difference between said first grid electrode and said second grid electrode in which said first potential difference is

substantially continuous and a pulsating light source irradiates said second layer.

11. In combination with image means for creating a conductivity-image in a layer of material exhibiting the property of electron-bombardment-induced conductivity, a conductive first layer adjacent one face of said layer, a photoelectrically-emissive second layer on the other face of said layer, an electron-receiving screen spaced from said second layer, a first grid electrode and a second grid electrode serially positioned between said second layer and said electron-receiving screen, circuit means to impress a first potential difference between said



first grid electrode and said layer of electron-bombardment-induced conductivity material and a second potential difference between said first grid electrode and said second grid electrode in which the first potential difference approximates a sawtooth wave form.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,544,755 | Johnson et al. | Mar. 13, 1951 |
| 2,667,585 | Gradstein | Jan. 26, 1954 |
| 2,683,832 | Edwards et al. | July 13, 1954 |