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ELECTRON-OPTICAL IMAGE INTENSIFIER SYSTEM

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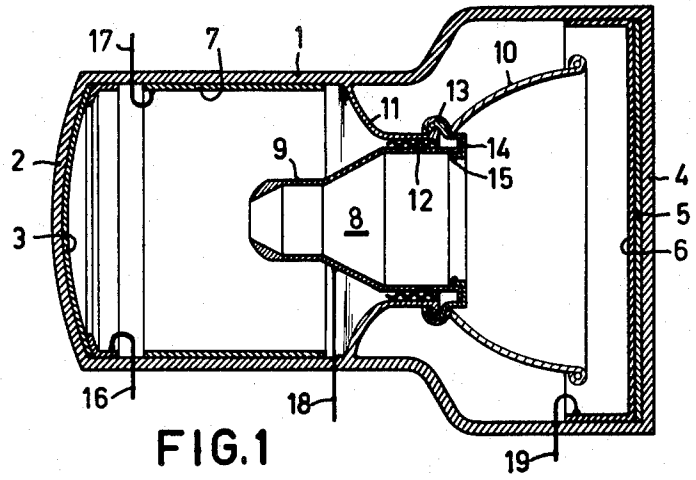


FIG.1

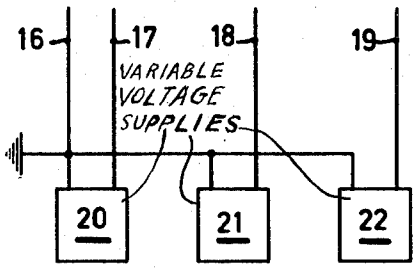


FIG. 2

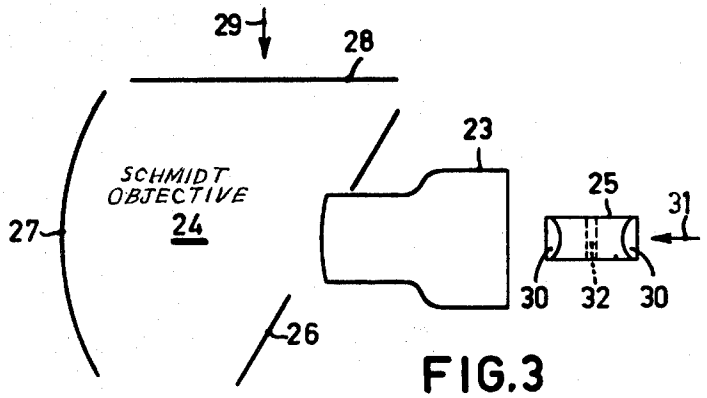


FIG.3

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ELECTRON-OPTICAL IMAGE INTENSIFIER SYSTEM

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16 Claims. (Cl. 250—213)

The present invention relates to image intensifier systems and to electron-optical image converter tubes suitable for use in such systems.

An electron-optical image converter tube is defined as comprising an evacuated envelope having a first face on the surface of which is provided a photo-emissive layer for acting as a photo-cathode and a second face on the surface of which is provided a phosphor layer and a conductive layer for acting as an anode.

In operation, an image is produced on the photo-cathode which emits electrons. The electrons are accelerated towards and focused on the anode so that an image corresponding to that produced on the photo-cathode is provided by the excitation of the phosphor layer. The focusing may be electromagnetic or electrostatic.

According to a first aspect of the present invention, an image-intensifier system comprises an electron-optical image converter tube as herein defined and adapted to provide variable magnification, means for producing a radiation image on the photo-emissive layer, an arrangement for viewing or recording an intensified image produced by the phosphor layer and means to vary the magnification of the tube.

If an image intensifier system is used at low levels of incident radiation, a small variation in the level is found to make a great difference to the discrimination of detail which is possible. The system according to the present invention provides the facility that for a particular low level of incident radiation, the magnification of the image provided by excitation of the phosphor layer may be adjusted to give optimum discrimination. With such a system, if the level of incident radiation increases, the magnification may be increased and a higher degree of discrimination obtained.

The image produced on the photo-cathode may be of visible, infrared ultra-violet or X-ray wavelength, it being necessary to provide for any intended use that the photo-emissive layer is stimulated to emit electrons by the incident radiation.

The system may comprise a wide-aperture lens system for focusing the radiation image on the photo-emissive layer, having a light-gathering power of at least 25 times that of the dark-adapted eyes. The "light-gathering power" may be at least 100 times that of the "dark-adapted" eyes.

At intensities a great deal lower than daylight intensity, the light is too weak to stimulate the nerve cells of the retina of the eye which enable them to see in strong light. However, other highly sensitive cells in the retina now take over the function but this process takes considerable time and is known as dark-adaptation. The "light-gathering power" of a lens is a measure of the quantity of light falling on the image surface. It is proportional to the square of the diameter of the lens and to more exactly define the relation it may be assumed that a lens having an aperture of at least 4 cms. has a "light-gathering power" of at least 25 times that of the "dark-adapted" eyes.

If the lens system for focusing a radiation image on the photo-cathode layer is of the Schmidt type the necessary light gathering power is readily available.

The system may comprise a Ramsden type eyepiece for viewing the intensified image and having an "exit pupil" greater than 7.7 mms.

"Exit pupil" is defined by Chambers' technical dictionary as an imaginary aperture for a telescope or microscope, limiting the emergent beam of light where its cross-sectional area is the least. It is usually the image of the objective formed by the eye piece and is at the position which should be occupied by the eye of the observer. In this respect the definition of the entrance pupil should be considered, which is the diaphragm, which limits the diameter of the cone of rays entering an optical system, which consequently is the diameter of the iris diaphragm of the eye. In the condition of dark-adaptation the diameter is 8–10 mms. so that the suggested "exit pupil" of the objective of 7.7 mms. gives almost optimum results.

According to a second aspect of the present invention an electron-optical image converter tube as herein defined comprises, between the first and second faces, a focus electrode and a first anode, the conductive layer provided on the second face being termed the second anode, the photo-emissive layer, the focus electrode and the first anode forming a first electron lens system for providing an intermediate, virtual image, the image formed by the first image of a two lens system which serves as the object for the second lens, and the first anode and second anode forming a second electron lens system for acting as a converging lens with a steady voltage of the second anode and in a range of potentials of the first anode less than the steady voltage of the second anode, whereby variable magnification is provided by the tube on variation of the potential of the first anode with consequent adjustment of the potential of the focus electrode. The intermediate virtual image lies outside the tube and is focused on the phosphor layer by the converging action of the second electron lens system.

The first electron lens system may be adapted to provide a field distribution substantially corresponding to the field distribution between concentric spheres.

The first electron lens system may be adapted to provide an inverted virtual image and the second electron lens system may be adapted to provide a real image at the phosphor layer which is inverted relative to the radiation image on the photo-emissive layer. The photo-emissive layer may be concave towards the first anode and the first anode, convex towards the photo-emissive layer, may have a central aperture for passage of electrons towards the phosphor layer.

The first anode may be substantially a figure of revolution having a first part, nearer to and convex towards the photo-emissive layer, in the form of a cap with a central aperture and a second part, nearer the second anode, in the form of a bell with its larger end open towards the second anode. The second anode may be in the form of a cylinder closed at one end and at its other end overlapping the first anode in the longitudinal direction of the tube. The focus electrode may be substantially cylindrical and overlap the first anode in the longitudinal direction of the tube. The focus electrode may be a conductive coating provided on the inner wall of the tube. The longitudinal axial distance between the photo-emissive layer and the first anode may be between 0.5 and 1.5 times the diameter of the focus electrode.

The diameter of the larger end of the bell may be at least twice, and may be at least three times, the shortest distance between the first and second anodes.

One embodiment of a system and a tube according to the present invention will now be described, by way of example, with reference to the accompanying diagrammatic drawing, in which:

FIGURE 1 is an axial cross-section of an electron-

optical image converter tube according to the second aspect of the present invention; and

FIGURE 2 shows a manner in which the tube may be connected to a voltage supply system and FIGURE 3 shows a manner in which the tube may be optically arranged, as part of an image intensifier system according to the first aspect of the present invention.

Referring now to FIGURE 1, an electron-optical image converter tube comprises an envelope 1 having a first face 2 convex towards the outside of the tube and on the internal surface of which is provided an antimony-caesium photo-cathode layer 3, which emits electrons when visible radiation is incident thereon, and a second face 4 on the internal surface of which is provided a phosphor layer 5 of a sulphide, which emits green light when irradiated with electrons. A thin conductive layer 6 of aluminum is provided on top of the layer 5 and in operation of the tube acts as a second anode. The layer 6 is continued over the longitudinal wall of the envelope 1 and has the form of a cylinder closed at one end.

A focus electrode 7 is provided on the inner cylindrical wall of the tube adjacent the first face 2 and comprises a cylindrical conductive coating of aluminum.

A first anode 8 is substantially a figure of revolution and comprises a first part 9 turned from aluminum and a second part 10 spun from aluminum.

The part 9 is in the form of a cap which is convex towards the photo-emissive layer 3 and has a central aperture for passage of electrons towards the phosphor layer 5. The part 10 is in the form of a bell with its larger end open towards the second anode 6.

In the longitudinal direction of the tube, the first anode 8 overlaps the focus electrode 7 at one end and the second anode (layer 6) at the other. The first anode is supported from a glass projection 11 projecting from the envelope 1. Both the first anode 8 and the projection 11 are figures of revolution. The part 9 is held on the projection 11 with the aid of a crimped stainless-steel spring 12 and the part 10 is secured in position by being spun over an annular thickening 13 provided at the end of the projection 11. The parts 9 and 10 are connected together by two lengths of platinum tape 14 secured between the part 10 and the thickening 13 when the part 10 is spun-over and secured to the part 10 by spot wells 15.

Connections are provided to the layer 3, the electrode 7, the first anode 8 and the layer 6 by conductors 16, 17, 18 and 19, respectively.

The layer 3, the electrode 7 and the first anode 8 form a first electron lens system which, in use, provides an intermediate, virtual image outside the face 4. The first and second anodes form a second electron lens system which is converging and provides a real image, which may still be inverted, by electron-excitation of the phosphor layer 5.

Preferably the first electron lens system provides a field distribution substantially corresponding to the field distribution between concentric spheres and may produce an inverted virtual image. Also, the converging effect of the second electron lens system is preferably operative only over a short distance.

The longitudinal axial distance between the first anode 8 and the layer 3 may preferably be between 0.5 and 1.5 times the diameter of electrode 7 and the diameter of the larger end of the part 10 at least twice or three times the shortest distance between the first and second anodes.

FIGURE 2 shows the conductors 16, 17, 18 and 19 connected to a voltage supply system. The supply system comprises three variable supply units 20, 21 and 22 having a common earth.

Approximate dimensions in mms. of a particular tube are as follows:

Length	270
Diameter at electrode 7	102
Diameter at second anode layer 6	115
Overlap between electrode 7 and first anode 8	15
Overlap between first and second anodes 8 and 6	10
Length of first anode 8	126
Distance between first anode 8 and layer 5	39
Radius of curvature of first face 2	180
Radius of curvature of cap of part 9	15
Diameter of aperture in cap of part 9	11
Smallest diameter of opening in part 10	50
Largest diameter of opening in part 10	96

In operation, the layer 3 is maintained at ground potential, the potential of the focus electrode 7 is adjustable in the range 0 v. to 600 v., the potential of the first anode 8 is adjustable in the range 0 v. to 10 kv. and the potential of the layer 6, constituting the second anode is maintained at 10 kv.

Different magnifications are provided by adjustment of the potential of the first anode 8. In accordance with the commonly known law of refraction on electron optics, the refraction index is determined by

$$n=\frac{U_2}{U_1}$$

in which U_2 and U_1 indicate the potentials on opposite sides of a refraction plane. In the case of an electrostatic electron lens the potential gradient along the optical axis varies according to the accelerating voltage and the refraction index at successive equi-potential planes depends on the potential gradient. In consequence of variation of the accelerating voltage the overall refraction index varies accordingly and while the electron optical magnification depends on the value of the refraction index it is clear that variable magnification is provided by varying of the potential of the focus electrode 7 to provide optimum focusing.

Operational data obtained in practice with this particular tube are:

POTENTIAL

Focus electrode V	First anode kv.	Magnification
75	5	0.19
90	1	0.32
140	2	0.51
200	3	0.64
270	4	0.70
330	5	0.77
390	6	0.83
440	7	0.87

With this particular tube, if the potential of the first anode is less than that of the second anode, the operation of the system comprising the layer 3, the overlapping focus electrode 7 and the first anode 8 is substantially stable in that an intermediate image of substantially the same magnification is provided at substantially the same position for a wide range of potentials of the first anode. The system comprising the first and second anodes (8, 6), with the first anode 8 at a potential lower than that of the second anode 6, constitutes a converging electrostatic lens, the converging effect of which increases with increase of the potential difference so that overall a variable magnification system is provided, magnification being variable by variation of the potential of the first anode 8 with consequent adjustment of the potential at the focus electrode 7 to obtain optimum focusing for the different potentials of the first anode 8.

The tube described above is of particular use in providing image intensification at low image intensities in varying conditions since a larger image may readily be provided when a sufficiently brighter object or scene is concerned with the consequent increase in resolution which is possible.

In general, the spacing between the first and second anodes may be chosen so that an amount of barrel distortion is introduced in the first and second anode sys-

tem to compensate for the pin-cushion produced by the cathode-focus electrode-first anode system. In general, balance is preferably provided at about the centre of the magnification range for the steady potentials to be applied in operation of the tube.

In the complete optical system shown in FIGURE 3, the tube **23** is associated with an objective system **24** and an eyepiece **25**.

The objective system is of the Schmidt type comprising a plane mirror **26**, apertured to permit incident radiation to strike the first face of the tube **23**, a spherical mirror **27** and a corrector plate **28**. The direction of the incident radiation is shown by the arrow **29**. With a corrector plate **28** having a diameter of 9½", such a system has a light gathering power 300 times that of the dark-adapted eyes.

The eyepiece **25** is of the Ramsden type having two plano-convex lenses **30** to which the eye is applied in the position indicated by the arrow **31**. The eyepiece **25** has an exit pupil greater than 7.7 mms. An intermediate optical element **32** may be included in the eyepiece **25** as is shown in broken lines to provide a desired final correction of the image provided. The eyepiece **25** may cover the whole of the image field of the tube **23** when the tube **23** is operating at its smallest magnification.

What is claimed is:

1. An electron-optical image converter tube comprising a first portion transmissive to radiation and a second light-transparent portion, a photo-emissive layer positioned to receive radiation transmitted through said first portion, a luminescent screen positioned within said envelope to be viewed through said second portion, first and second anode electrodes positioned intermediate said photo-emissive layer and said luminescent screen, a focussing electrode positioned intermediate said photo-emissive layer and said first anode for focussing an electron image produced on said photo-emissive layer by radiation incident thereon onto the luminescent layer, said focussing electrode and said first anode electrode constituting a first electron lens system for providing an intermediate virtual image of the electron image on the photo-emissive layer, said first and second anode electrodes constituting a second electron lens system serving as a converging lens with a constant potential applied to the second anode electrode, means to apply a given potential to said second anode, means to apply a focussing potential to the focussing electrode, and means to apply a potential to the first anode which is less than that applied to the second anode including means to vary the potential applied to the first anode whereby variable magnification of the image produced on the luminescent screen is achieved.

2. An image intensifier system as claimed in claim **1** in which the first portion for transmitting the radiation to the photo-emissive layer includes a wide aperture lens system for focussing a radiation image on the photo-emissive layer, said lens system having a light-gathering power of at least 25 times that of dark-adapted eyes.

3. An image intensifier system as claimed in claim **2** in which the lens system has a light-gathering power of at least 100 times that of dark-adapted eyes.

4. An image intensifier system as claimed in claim **2** in which the lens system is a Schmidt optical system,

5. An image intensifier system as claimed in claim **1** including means to view the image on the luminescent screen comprising a lens system having an exit pupil greater than 7.7 mms.

6. A tube as claimed in claim **1**, in which the first electron lens system comprises means to provide a field distribution substantially corresponding to the field distribution between concentric spheres.

7. A tube as claimed in claim **1**, in which the first electron lens system comprises means to provide an inverted virtual image.

8. A tube as claimed in claim **7**, in which the second electron lens system comprises means to provide a real image on the luminescent screen which is inverted relative to the electron image on the photo-emissive layer.

9. A tube as claimed in claim **1**, in which the photo-emissive layer is concave towards the first anode and the first anode is convex towards the photo-emissive layer and has a central aperture for passage of electrons towards the luminescent screen.

10. A tube as claimed in claim **1**, in which the first anode is substantially a figure of revolution and has a first part, nearer to and convex towards the photo-emissive layer, in the form of a cap with a central aperture and a second part, nearer the second anode, in the form of a bell with its larger end open towards the second anode.

11. A tube as claimed in claim **10**, in which the second anode is in the form of a cylinder closed at one end at its other end overlapping the first anode in the longitudinal direction of the tube.

12. A tube as claimed in claim **1**, in which the focussing electrode is substantially cylindrical and overlaps the first anode in the longitudinal direction of the tube.

13. A tube as claimed in claim **12**, in which the focussing electrode is a conductive coating provided on the inner wall of the tube.

14. A tube as claimed in claim **12** in which the longitudinal axial distance between the photo-emissive layer and the first anode is between 0.5 and 1.5 times the diameter of the focussing electrode.

15. A tube as claimed in claim **11**, in which the diameter of the larger end of the bell is at least twice the shortest distance between the first and second anodes.

16. A tube as claimed in claim **15**, in which the diameter of the larger end of the bell is at least three times the shortest distance between the first and second anodes.

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