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Hagar

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[54] **GATEABLE IMAGE INTENSIFIER TUBE**

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[52] **U.S. Cl.**...............**250/213 VT,** 313/65 R, 315/16

[51] **Int. Cl.**...........................**H01j 31/50,** H01j 39/12

[58] **Field of Search** ....250/213 VT; 313/65 R; 315/16

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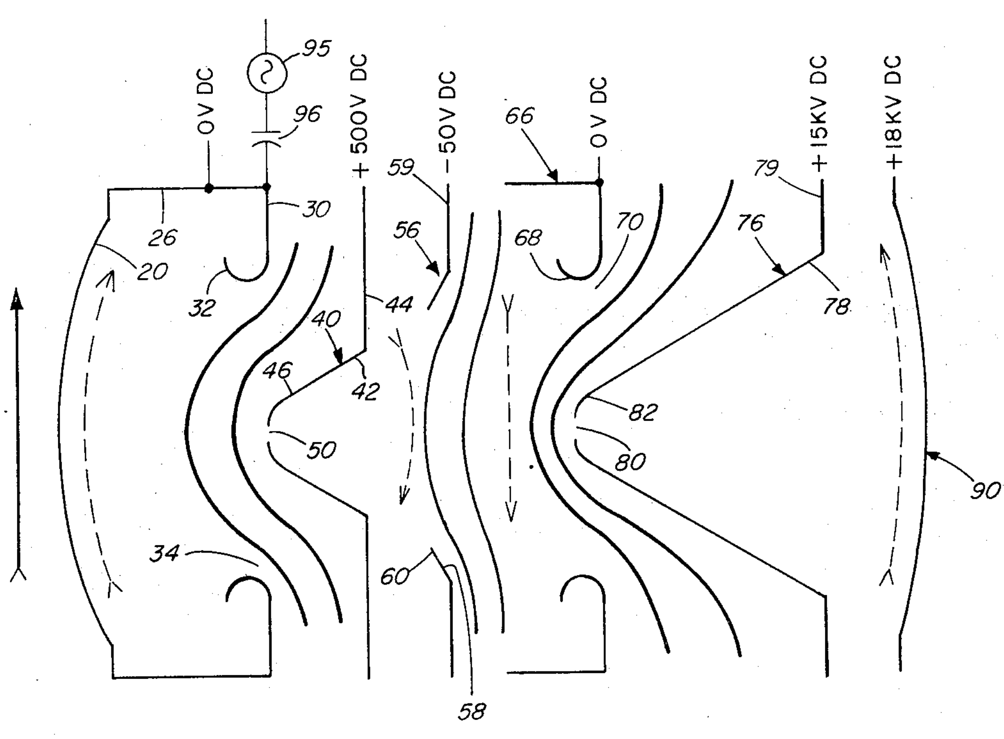
[57] **ABSTRACT**

An image intensifier tube comprising an elongated envelope having therein axially spaced electrodes including a gateable photocathode located adjacent an input faceplate at one end of the envelope and low voltage means for increasing the intensity of an electrostatic field adjacent the photocathode without adversely affecting other interelectrode fields established within the tube envelope, thereby achieving an in-focus image having substantially constant brightness during the gating interval.

7 Claims, 3 Drawing Figures



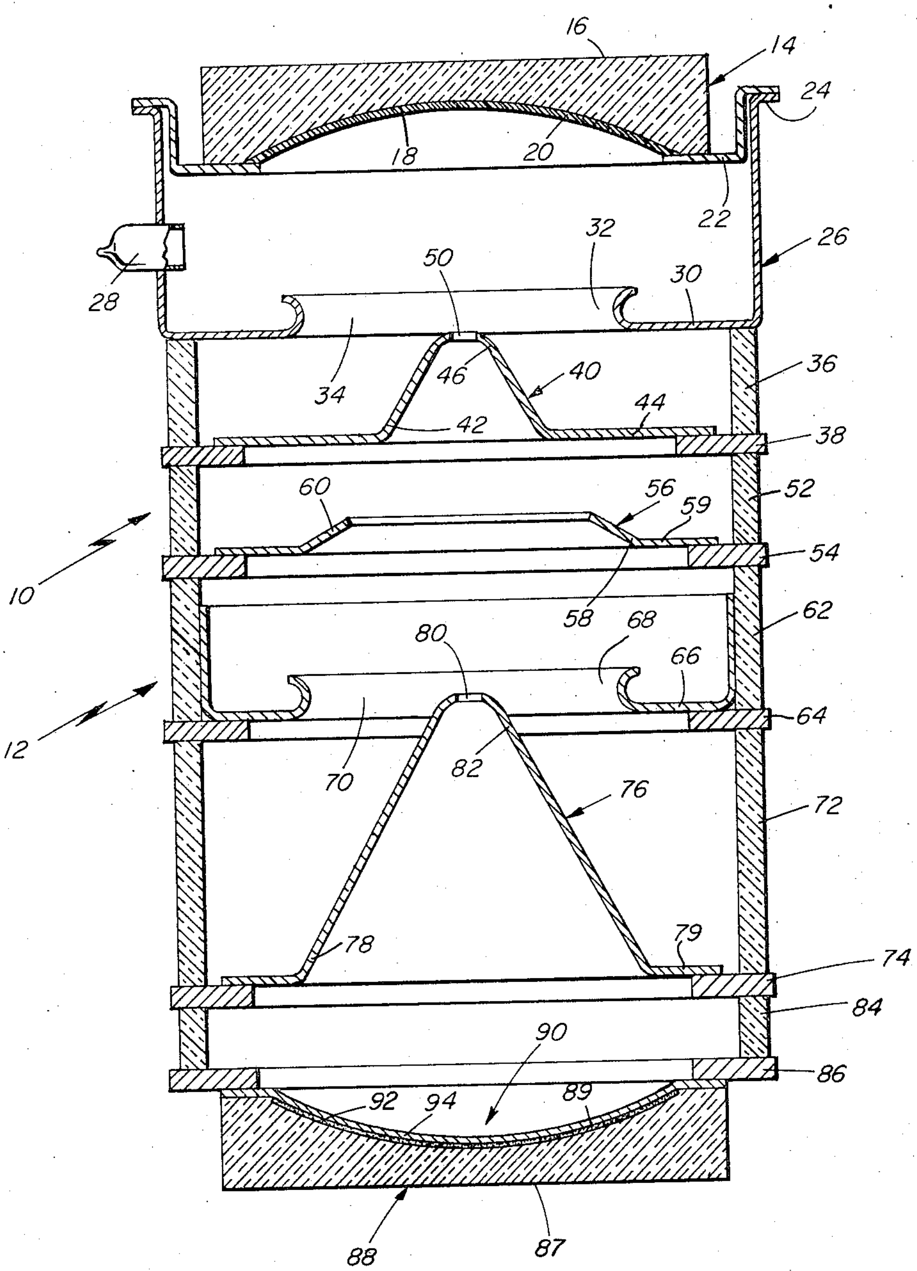

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FIG. 1

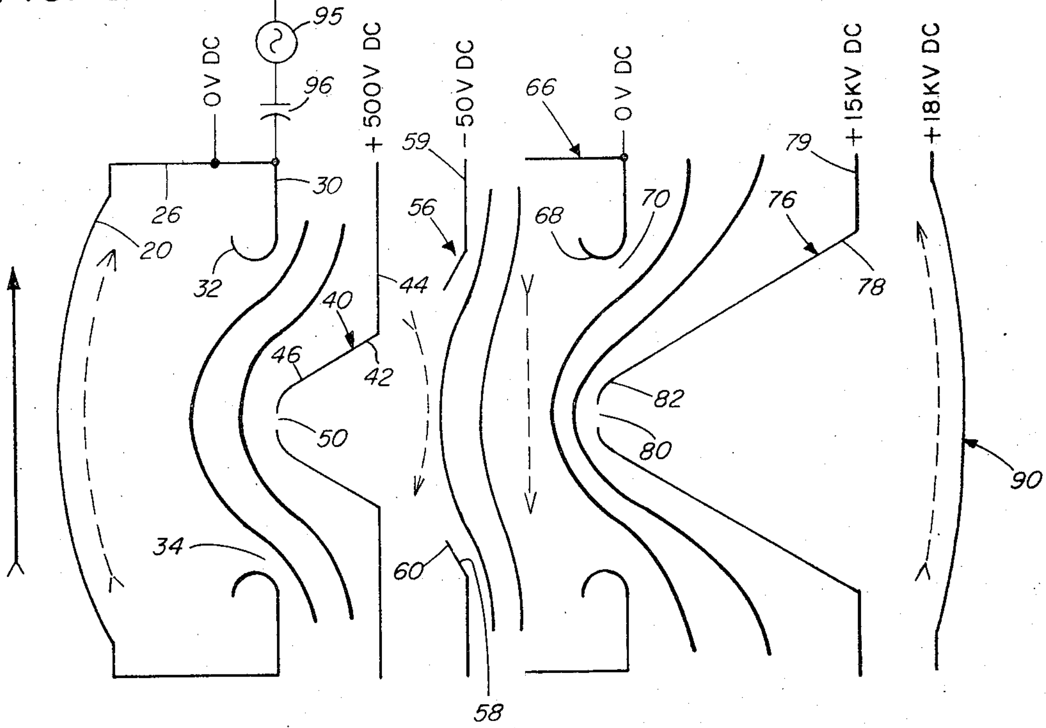
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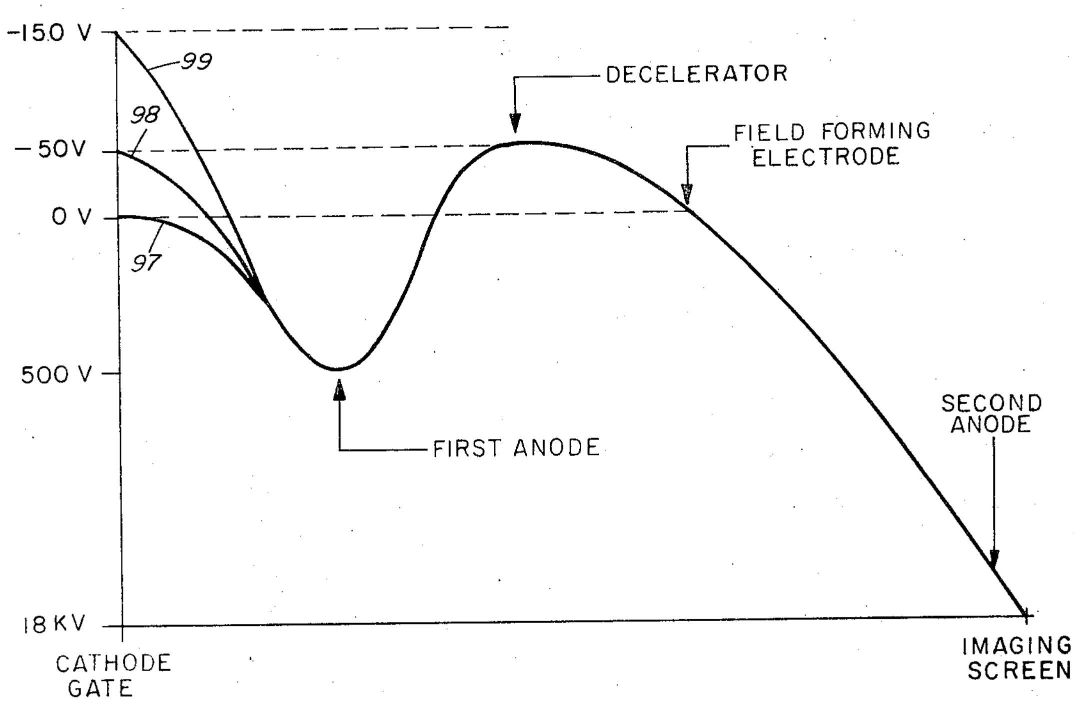
FIG. 2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-50V
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18 KV
DECELERATOR
FIELD FORMING
ELECTRODE
FIRST ANODE
SECOND
ANODE
CATHODE
GATE
IMAGING
SCREEN

FIG. 3

GATEABLE IMAGE INTENSIFIER TUBE

BACKGROUND OF THE INVENTION

This invention relates generally to image amplifier tubes and is concerned more particularly with a gateable image intensifier tube for producing an in-focus image having substantially constant brightness during a gating interval.

An image intensifier tube basically comprises a diode having an elongated envelope wherein a photocathode is disposed in axially spaced relationship with an imaging screen assembly. Usually, the photocathode comprises a layer of photoemissive material which generally is disposed adjacent an input faceplate at one end of the envelope, and the imaging assembly comprises a layer of phosphor material which generally is disposed adjacent an output faceplate at the other end of the envelope. The imaging screen assembly usually is maintained at a relatively high positive potential with respect to the photocathode for the purpose of establishing a strong electrostatic field therebetween.

In operation, photons of radiant energy emanate from localized areas of an external object and, after optical focussing, pass through the input faceplate of the tube to impinge on corresponding localized areas of the photocathode. As a result, the photocathode emits an equivalent electron image which is accelerated by the strong electrostatic field and focussed on the imaging screen assembly. The accelerated electron image, thus amplified, impinges on the phosphor layer of the imaging screen assembly with sufficient kinetic energy to produce a corresponding visual image which may be viewed through the output faceplate of the tube.

In certain instances, it may be advantageous to operate an image intensifier tube only intermittently, such as when viewing a scene illuminated by a pulsed light source, for example. Therefore, the image intensifier tube may be provided with electronic gating means for switching the tube from a non-operating to an operating condition and back to a non-operating one after a predetermined time interval, as with a square wave pulse generator, for example. However, when switching a diode-type image intensifier tube as described, a definite amount of time and a great deal of energy is utilized in charging the capacity of the electrodes to characteristically high operating voltages, such as fifteen thousand volts, for example, and then controllably discharging the electrodes at the completion of the gating interval. Consequently, an undesirably large and expensive power supply is required for producing a gating voltage of this magnitude and maintaining it within tight limits in order to achieve maximum resolution. Even under ideal conditions, the brightness of the output image will vary noticeably during the rise and decay times of the gating pulse as well as during any overshoot and sag intervals thereof.

Alternatively, a grid may be insulatingly disposed between the photocathode and the imaging screen assembly, and be biased at a suitable potential for gating purposes. However, an annular type of grid still would require a large gating voltage, such as several thousand volts, for example, which would call for an excessively large and expensive power supply to produce the gating voltage and maintain it within the necessary tight limits. Also, the tube would be out of focus during the entire rise and decay times of the pulse as well as during any overshoot and sag intervals thereof. Although a fine mesh type of grid would require a lower gating voltage, it would reduce image transmission thereby decreasing image brightness and tube gain. Also, since the fine mesh grid generally is disposed in close proximity to the photocathode, it would increase the input capacitance of the tube, thus adversely affecting the response of the tube to rapid gating signals. Furthermore, the fine mesh type of grid would increase the possibility of field emission of flash-overs occurring as well as increasing background noise due to vibration of the mesh, all of which cause visual defects to appear in the output image. Thus, the prior art does not provide satisfactory means for gating an image intensifier tube, such that a relatively low gating voltage will produce an in-focus image and the resulting output image will have substantially constant brightness during the gating interval.

SUMMARY OF THE INVENTION

Accordingly, this invention provides an image intensifier tube which may be switched from a condition of readiness to a fully operating condition by applying a relatively small signal voltage to the photocathode of the tube, thus causing a temporary increase in the intensity of an accelerating field established adjacent the photocathode without substantially changing the shape of the accelerating field or adversely affecting other electrostatic fields established within the tube.

A preferred embodiment of this invention may comprise an elongated envelope having axially spaced electrodes therein including a spherically curved photocathode disposed adjacent an input faceplate at one end of the envelope and having a biasing potential applied thereto, a first frusto-conical anode maintained at a relatively high positive potential with respect to the photocathode, a decelerating grid annulus maintained at a slightly negative potential with respect to the photocathode, a field shaping electrode maintained at approximately the same potential as the photocathode, a second frusto-conical anode maintained at a higher positive potential than the first anode, and an imaging screen disposed adjacent an output faceplate at the other end of the tube envelope and maintained at the same potential as the second anode or slightly positive relative thereto.

As described, this novel tube normally is biased in a condition of readiness by having established between the photocathode and the first anode a first accelerating field which is counteracted by a slightly stronger decelerating field established between the first anode and the decelerating grid annulus. Thus, an electron image emitted from the photocathode, after being focussed and accelerated by the first accelerating field, will pass through the first anode. Upon entering the decelerating field, the progress of the electron image toward the second anode will be retarded to such an extent that the electron image will be attracted back to the first anode. Consequently, the electron image will not reach the imaging screen to produce a corresponding visible image.

The described tube is turned "on" by having a negatively directed voltage pulse of predetermined value and duration applied to the photocathode. As a result, the photocathode will be driven in the negative direction a predetermined amount with respect to the first anode and the decelerating grid annulus; and the first accelerating field will become stronger than the decelerating field for the predetermined time duration of the pulse. However, while the intensity of the first accelerating field is increasing, the shape of this field will remain substantially unchanged, since it is determined by the opposing surface contours of the photocathode and the anode, respectively. Consequently, an image emitted from the photocathode is maintained in focus during the entire gating interval, including the rise and decay times of the gating pulse as well as during any overshoot and sag portions thereof. Thus, an electron image emitted during the gating interval still will be focused through the first anode but will travel at higher velocities than previously and, consequently, will attain correspondingly higher levels of kinetic energy. As a result, the electron image will pass through the decelerating field and enter a second accelerating field established between the field forming electrode and the second anode.

Although the focussing of the electron image does not change during the gating interval, the speed of the image travelling toward the second accelerating field does vary with changes in the intensity of the first accelerating field. Consequently, the intensity of the second accelerating field is made considerably greater than the first accelerating field, such that changes in the intensity of the first accelerating field will be negligible when compared to the overall intensity of the second accelerating field. As a result, the second accelerating field will focus the electron image through the second anode and accelerate it to a substantially uniform kinetic energy level during the gating interval. Thus, the image will impinge on the imaging screen assembly and produce an output visual image having substantially constant brightness throughout the gating interval.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of this invention, reference is made to the drawing, wherein:

FIG. 1 is an axial sectional view of an image intensifier tube embodying this invention;

FIG. 2 is a diagrammatic representation of the tube shown in FIG. 1 with typical voltages applied to the respective electrodes; and

FIG. 3 is a graphical representation of the voltages applied to the electrodes versus their relative positions in the tube.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawing wherein like characters of reference designate like parts, there is shown in FIG. 1 an image intensifier tube 10 including a generally tubular envelope 12 having at one end a transversely disposed, input faceplate 14. The faceplate 14, for example, may comprise a plurality of fiber optic rods which are hermetically sealed in side-by-side relationship to form a cylindrical bundle. The described fiber optic faceplate, preferably, is provided with a substantially flat outer surface 16 and a centrally disposed, concave inner surface 18.

The concave inner surface 18 is axially aligned with an opening in a support ring 22 which is made of conductive material, such as kovar, for example, Support ring 22 is hermetically attached to faceplate 14 by conventional means, such as epoxy cement, for example. Deposited on the concave surface 18 is a conforming photocathode 20 comprising a conductive layer of photoemissive material, such as cesium antimonide, for example. Photocathode 20 has a circular edge disposed in electrical contacting relationship with an annular portion of ring 22, adjacent its inner periphery. An outer marginal portion of ring 22 is circumferentially attached, as by welding, for example, to a contiguously disposed, radial flange 24 which constitutes the cathode terminal of tube 10.

Flange 24 extends outwardly from one end of an axially disposed cathode sleeve 26 which is made of conductive material, such as kovar, for example. Transversely disposed in the wall of sleeve 26 is an exhaust tubulation 28 through which the envelope 12 is evacuated during processing of the tube and which is sealed off after processing is completed. The other end of sleeve 26 is provided with an inwardly extending, radial flange 30 having an inner rolled edge 32 which forms a centrally disposed aperture 34. The aperture 34 is axially aligned with the opening in ring 22 such that the rolled edge 32 and the inner surface of photocathode 20 form a spherically curved equipotential surface when a suitable potential is applied to the cathode terminal 24.

The field forming flange 30 is hermetically attached by conventional means to one end of an axially disposed, hollow cylinder 36 which is made of dielectric material, such as ceramic, for example. The other end of cylinder 36 is peripherally sealed by suitable means to one side of a substantially flat ring 38 which is made of conductive material, such a kovar, for example. Ring 38 constitutes the first anode terminal of the tube and extends inwardly of envelope 12 to support a frusto-conical, first anode sleeve 40 which is made of conductive material, such as stainless steel, for example. Anode sleeve 40 is provided with a large diameter, open end 42 having an outwardly extending, radial flange 44 which is fixedly attached, as by welding, for example, to an inner annular portion of ring 38. Anode 40 extends longitudinally through cylinder 36 and terminates in a small diameter end 46 which is insulatingly disposed within the aperture 34. The small diameter end 46 is provided with a centrally disposed aperture 50 which is axially aligned with a central portion of photocathode 20.

The other side of ring 38 is circumferentially attached by conventional means to one end of an axially disposed, hollow cylinder 52 which is made of dielectric material, such as ceramic, for example. The other end of cylinder 52 is peripherally sealed by suitable means to one side of a substantially flat ring 54 which is made of conductive material, such as kovar, for example. Ring 54 constitutes a grid terminal of the tube and extends inwardly of envelope 12 to support a coaxially disposed, frusto-conical grid ring 56 which functions as a decelerator electrode. Grid ring 56 is made of conductive material, such as stainless steel, for example, and has a large diameter open end 58 provided with an outwardly extending radial flange 59 which is fixedly attached, as by welding, for example, to an inner annular portion of ring 54. Grid ring 56 has an opposing, small diameter open end 60 which is disposed in spaced axial relationship with the large diameter open end 44 of first anode sleeve 42, such that the tapering wall of grid ring 56 is aligned with the tapering wall of anode sleeve 40 and electrostatically appears to be a continuation thereof.

The other side of ring 54 is circumferentially attached, by conventional means, to one end of an axially disposed cylinder **62** which is made of dielectric material, such as ceramic, for example. The other end of cylinder **62** is peripherally sealed, by suitable means, to one side of a substantially flat ring **64** which is made of conductive material, such as kovar, for example. Ring **64** constitutes a field forming terminal of the tube and extends inwardly of envelope **12** to support a coaxially disposed, field forming ring **66** which is made of conductive material, such as stainless steel, for example. An outer annular portion of ring **66** is fixedly attached, as by welding, for example, to an inner annular portion of terminal ring **64**. Field forming ring **66** is provided with an inner rolled edge **68**, which forms a centrally disposed aperture **70**, in axial alignment with the larger diameter end of grid ring **56**. The field forming ring **64** has a configuration which is similar to the configuration of the cathode flange **30** and which performs a similar function.

The other side of terminal ring **64** is circumferentially attached by conventional means to one end of an axially disposed cylinder **72** which is made of dielectric material, such as ceramic, for example. The other end of cylinder **72** is peripherally sealed by suitable means to one side of a substantially flat ring **74** which is made of conductive material, such as kovar, for example. Ring **74** constitutes the second anode terminal of the tube and extends inwardly of envelope **12** to support a second frusto-conical anode sleeve **76** which is made of conductive material, such as stainless steel, for example. Anode sleeve **76** is provided a large diameter, open end **78** having an outwardly extending flange **79** which is fixedly attached, as by welding, for example, to an inner annular portion of ring **74**. The second anode **76** extends longitudinally through cylinder **72** and terminates in a small diameter end **82** which is insulatingly disposed within the aperture **70**. The small diameter end **82** is provided with a centrally disposed aperture **80** which is axially aligned with the aperture **50** in the small diameter end **42** of first anode sleeve **40**.

The other side of ring **74** is circumferentially attached, by conventional means to one end of an axially disposed cylinder **84** which is made of dielectric material, such as ceramic, for example. The other end of cylinder **84** is peripherally sealed, by suitable means, to one side of a substantially flat ring **86** which is made of conductive material, such as kovar, for example. Ring **86** constitutes the imaging screen terminal of the tube and supports a coaxially disposed output faceplate **88** which closes the other end of envelope **12**.

Output faceplate **88** is similar to input faceplate **14** and may comprise a bundle of fiber optic rods hermetically sealed in side-by-side relationship to form a cylindrical bundle. The described fiber optic faceplate may be provided with a flat outer surface **87** and a centrally disposed, concave inner surface **89**, which carries an imaging screen assembly **90**. The imaging screen assembly **90** includes a layer **92** of phosphor material, such as zinc cadmium sulfide, for example, which may be deposited directly on the concave inner surface **89**, and a conductive film **94** of light reflecting material, such as aluminum, for example, which may be disposed directly on the inner surface of phosphor layer **92**. The conductive film **94** has an outer annular portion which is circumferentially attached to the imaging screen terminal ring **86**. A central portion of the imaging screen assembly **90** is axially aligned with the aperture **80** in the small diameter end **82** of the second anode sleeve **76**. Thus, tube **10** is provided with an axis of symmetry which extends from a central portion of photocathode **20**, through the apertures **50** and **80** in anode sleeves **40** and **76**, respectively, and terminates in a central portion of imaging screen assembly **90**.

Shown in FIG. 2 are typical values of steady-state voltages which may be applied to the described terminal rings of tube **10** in order to place the tube in a condition of readiness. For example, the photocathode **20** and electrically connected cathode sleeve **26** may be biased at approximately zero volts DC or ground potential, while the first anode sleeve **40** may be maintained at approximately five hundred volts positive and the decelerator grid ring **56** may be maintained at approximately fifty volts negative, with respect to the photocathode **20**. The field forming ring **66** may be maintained at approximately the bias potential of the photocathode **20**, while the second anode sleeve **76** may be maintained at approximately fifteen thousand volts positive and the imaging screen assembly may be maintained at approximately eighteen thousand volts positive, with respect to the photocathode **20**. It should be emphasized that the foregoing voltage values are stated herein merely for illustrative purpose and should not be construed as limiting this invention.

As a result of maintaining the respective electrodes of tube **10** at the suggested voltage values, there will be established between the concave inner surface **18** of photocathode **20** and the small diameter end **46** of first anode sleeve **40** an electron accelerating field having spherically curved, equipotential surfaces and orthogonally directed, intensity vectors. Thus, the photocathode **20** will emit a conformingly curved image which will be accelerated radially toward the small diameter end **46** of first anode sleeve **40**. Consequently, the image will converge toward a crossover region on the axis of symmetry and adjacent the aperture **50** in the small diameter end **46** of anode sleeve **40**. It has been found that variations in the voltage applied to the first anode sleeve **40** will change the intensity but will not significantly affect the shape of the spherically curved, equipotential surfaces of the accelerating field established between the photocathode **20** and the first anode. Consequently, an electron image emitted from photocathode **20** will remain in focus despite variations in the potential of the first anode sleeve **44**.

After passing through the crossover region, the image will be inverted and will travel through the first anode sleeve **40**, while diverging and assuming a curvature opposite to that of photocathode **20**. When nearing the larger diameter end **42** of anode sleeve **40** and after emerging therefrom, the electron image will travel through a decelerating electrostatic field. The voltage applied to the grid ring **56** is adjusted to a value which will just stop the progress of the electron image through the decelerating field. As a result, the image will be attracted back to the relatively positive first anode sleeve **40** and, consequently, will not appear on the imaging screen assembly **90** of the tube **10**.

However, by connecting a signal generator **95** through a suitable capacitor **96** to the photocathode **20**, a negative pulse of predetermined magnitude may be applied to the photocathode which will drive it negative with respect to the first anode sleeve **40** and the decelerating grid ring **56**. Thus, the accelerating electrostatic field between the photocathode **20** and the first anode sleeve **40** will become relatively stronger as compared to the decelerating electrostatic field between the anode sleeve **40** and the decelerating grid ring **56.** Since the photocathode **20** is driven negative while the potential of the first anode sleeve **40** remains unchanged, the intensity of the first accelerating field will be increased without adversely affecting the decelerating field or the second accelerating field.

As shown by the curve **97** in FIG. **3,** when the photocathode **20** is less negative than the decelerating grid ring **56,** the electrons in the image emitted from the photocathode will not acquire sufficient kinetic energy to overcome the potential "hill" represented by the grid ring **56.** As shown by curve **98,** even when the photocathode **20** is driven negative only to the cut-off potential of the decelerating grid ring **56,** the electrons in the image still will not acquire sufficient kinetic energy to pass over the potential "hill". However, as shown by curve **99,** when the photocathode **20** is driven more negative than the decelerating grid ring **56,** such as one hundred and fifty volts in this instance, for example, the electrons in the image will acquired more than the necessary kinetic energy to pass through the decelerating grid ring **56.**

As a result of passing through the decelerating field, the electron image will lost its reverse curvature and will become more planar. Thus, a nearly ideal "virtual image" will pass through the field forming ring **66** and enter the strongly accelerating electrostatic field established between the ring **66** and the highly positive second anode **76.** This second accelerating field also has spherically curved equipotential surfaces whereby the "virtual" image will be converted toward another crossover region, which is on the axis of symmetry and adjacent the aperture **80** in the small diameter end **82** of anode sleeve **76.** After passing through this second crossover region, the image will be reverted to its original orientation and will diverge, while travelling at relatively high velocity, through the second anode sleeve **76.**

Although the "virtual" image will be in focus when it enters the second accelerating field, all the electrons forming the image will not be travelling at substantially the same velocity, due to variations in the intensity of the first accelerating field during the gating interval. Thus, if the "virtual" image were to form a visible image in the vicinity of the field forming electrode **66,** the resulting image would be in focus but its brightness would vary with time in accordance with variations in the gating signal. Consequently, the second accelerating field is maintained at an intensity considerably greater than the intensity of the first accelerating field. For example, the 15,000 volts applied to the second anode sleeve **70** is one hundred times greater than the maximum magnitude of the gating voltage applied to the photocathode **20** in this instance. As a result, changes in intensity of the first accelerating field, during the gating interval, and consequent changes in electron velocities will be one percent or less than the overall intensity of the second accelerating field. Therefore, these variations in electron velocities will be negligible in comparison to the velocities of the electrons when passing through the second accelerating field. Consequently, the electrons forming the image will be travelling at substantially uniform velocity when they emerge from the second anode sleeve **76** and approach the imaging screen assembly **90.**

Due to the kinetic energy acquired in passing through the second accelerating field, the electron image will pass through the conductive film **94** of the imaging screen assembly **90** and impinge on the phosphor layer **92.** Since the electrons in the image are travelling at substantially uniform velocity, the phosphor layer **92** will produce a corresponding visible light image of substantially constant brightness during the gating interval. At the completion of the gating pulse, the photocathode **20** will return to its initial bias potential, and the decelerating field established adjacent the grid ring **56** again will prevent an electron image from reaching the imaging screen assembly **90,** as previously described.

Thus, there has been disclosed herein a novel image intensifier tube having a gateable photocathode to which a relatively small gating voltage may be applied for the purpose of increasing the intensity of a first accelerating field established between the photocathode and a first accelerating electrode without adversely affecting other interelectrode fields established within the tube. Since a gating grid electrode is not positioned adjacent the photocathode, as in similar types of prior art tubes, the input capacitance of this inventive image intensifier tube is optimized for responding to rapid gating signals. Also, the possibility of field emission, flash-over and background noise occurring in the initial stage of the tube is minimized. By having the opposing surfaces of the photocathode and the imaging screen shaped to form the desired electrostatic field lines, an electron image emitted from the photocathode is maintained in focus during an entire gating interval including the rise and the decay times of a gating pulse as well as during any overshoot and sag portion thereof. Thus, a relatively low voltage may be applied to the first anode sleeve for the purpose of establishing the desired electrostatic field; and an electron image emitted from the photocathode will be maintained in focus despite any fluctuations in potential between the photocathode and the first anode sleeve.

Since the potential applied to the decelerator grid electrode is sufficient to just stop the progress of an electron image through the decelerating field, only a relatively small gating voltage applied to the photocathode is required for overcoming the effect of the decelerating field and turning this tube "on". Although the decelerator electrode, has been illustrated herein as a single ring, it may be replaced by a series of decelerator electrodes, each having a configuration other than that of a ring, such as a sleeve, for example. Also the second accelerating field may be established by a series of electrodes, each having a configuration other than the configuration of the field forming ring **66** or the second anode sleeve **76,** respectively.

From the foregoing, it will be apparent that all of the objectives of this invention have been achieved by the structures shown and described. It will be also apparent, however, that various changes may be made by those skilled in the art without departing from the spirit of the invention as expressed in the appended claims. It is to be understood, therefore, that all matter shown and described is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. A gateable image intensifier tube comprising:

an elongated envelope;

a photocathode disposed within the envelope adjacent one end thereof;

an imaging screen disposed within the envelope adjacent the other end thereof;

first means for establishing a first accelerating field adjacent the photocathode;

second means for establishing a second accelerating field adjacent the imaging screen, the second accelerating field having a greater intensity than the first accelerating field;

third means for establishing a decelerating field between the first and second accelerating fields, the decelerating field normally having a magnitude of intensity greater than that of the first accelerating field but less than that of the second accelerating field; and

fourth means for varying the intensity of the first accelerating field independently of the decelerating field and the second accelerating field.

2. A gateable image intensifier tube as set forth in claim **1** wherein the first means includes means for applying a bias potential to the photocathode.

3. A gateable image intensifier tube as set forth in claim **2** wherein the fourth means includes means for applying a gating signal voltage to the photocathode.

4. A gateable image intensifier tube as set forth in claim **3** wherein the signal voltage is sufficiently negative with respect to the bias potential to increase the

first accelerating field magnitude of intensity to a value greater than that of the decelerating field but less than that of the second accelerating field.

5. A gateable image intensifier tube as set forth in claim **2** wherein the first means includes an apertured electrode disposed within the envelope in spaced opposing relationship with the photocathode and means for maintaining apertured apertured electrode at a positive potential with respect to the photocathode.

6. A gateable image intensifier tube as set forth in claim **5** wherein the respective opposing surfaces of the photocathode and the apertured electrode are contoured to maintain the shape of the first accelerating field substantially unchanged despite changes in intensity of the first accelerating field.

7. A method of gating a photocathode of an image intensifier tube comprising the steps of biasing the photocathode at a predetermined potential, establishing an accelerating electrostatic field adjacent the photocathode and a decelerating electrostatic field of slightly greater intensity adjacent the accelerating field, and reducing the potential of the photocathode until the magnitude of intensity of the accelerating field is greater than the magnitude of intensity of the decelerating field.

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