United States Patent [19]

Lawrence et al.

[11] **3,864,595**

[45] **Feb. 4, 1975**

[54] **AUTOMATIC BRIGHTNESS CONTROL FOR GATED MICRO-CHANNEL PLATE INTENSIFIER**

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[22] Filed: **Apr. 19, 1973**

[21] Appl. No.: **352,825**

[52] **U.S. Cl.** ..... **315/12,** 313/103, 250/213 VT

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search** ..... 315/10-12; 313/103, 104, 105; 250/213 VT

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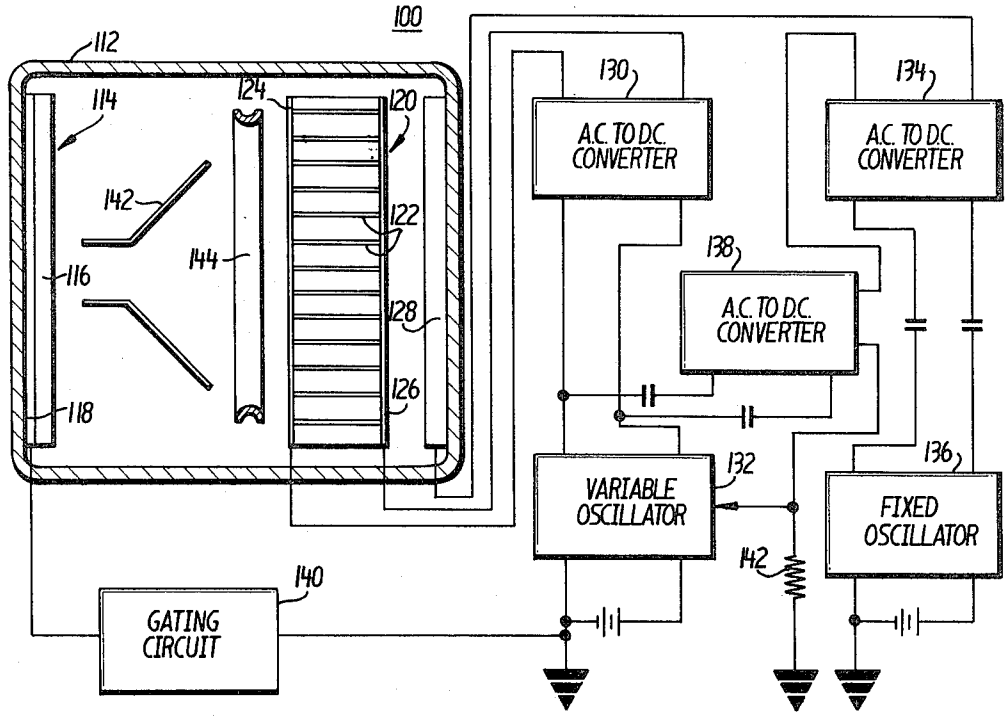
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Attorney, Agent, or Firm—D. Schron

[57] **ABSTRACT**

An image intensifier tube is described as including a photocathode element for converting an incident radiation image into a corresponding electron image, a micro-channel plate for multiplying the electron image, and a phosphorous screen for converting the multiplied electron image into a corresponding radiation image to be viewed. The electron image may be turned "on" and "off" by selectively applying a gating signal to the photocathode element. A potential applied between the first and second electrodes of the micro-channel plate is varied in accordance with the current absorbed at the second electrode to control the degree of electron multiplication and to prevent saturation of the phosphorous screen. In an illustrative embodiment, a variable potential source coupled to the electrodes of the micro-channel plate, includes a variable oscillator responsive to the current derived from the second electrode and an AC/DC converter for applying a DC potential whose magnitude corresponds to the variable frequency of this oscillator. Significantly, the supply source for the phosphorous screen includes first and second sections, the first section including an AC/DC converter connected to the aforementioned variable oscillator, for providing a variable potential between the second electrode of the micro-channel plate and the phosphorous screen, dependent upon the variable potential applied between the electrodes of the micro-channel plate. The second section includes illustratively a fixed oscillator and a third AC/DC converter whose output is connected to the phosphorous screen.

7 Claims, 2 Drawing Figures



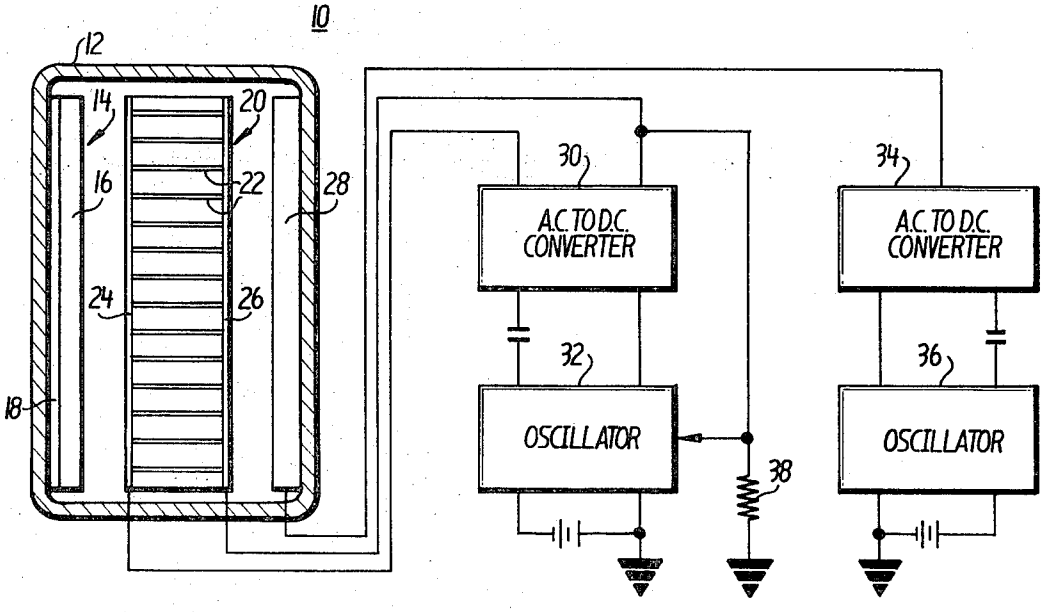


FIG. 1 PRIOR ART

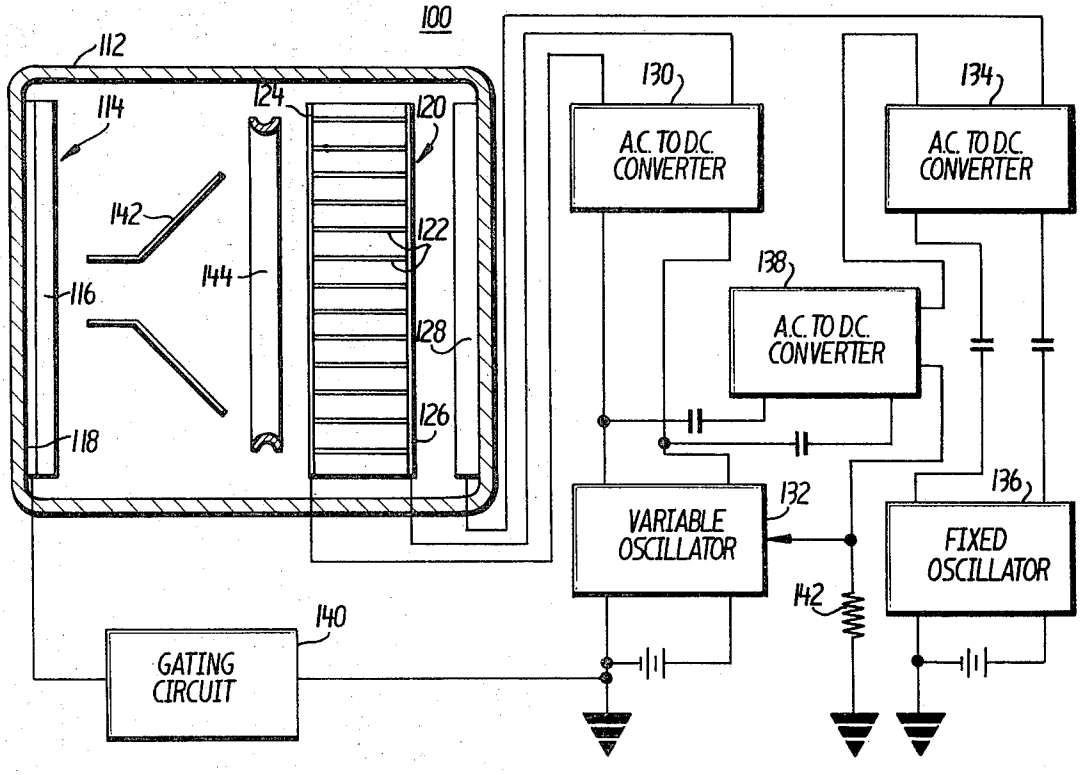


FIG. 2

AUTOMATIC BRIGHTNESS CONTROL FOR GATED MICRO-CHANNEL PLATE INTENSIFIER

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

This invention relates to image intensifiers and in particular to those image intensifiers including micro-channel plates.

2. Description of the Prior Art

There are many applications of image intensifiers for sensing and amplifying radiation images of low intensity. Typical of such apparatus are those vacuum tubes employing micro-channel plates for multiplying an electron image corresponding to the sensed radiation image. More specifically, such devices include a photocathode for converting the incident radiation image into a corresponding electron image which is multiplied by the micro-channel plate (MCP); the multiplied electron image is directed onto a phosphorous screen for providing an intensified display of the sensed radiation image. The gain is achieved by the micro-channel plate which includes a plurality of channels or passages, each presenting a secondaray emissive surface to the electrons. As the elelctrons of the image are directed through the channels, they repeatedly collide with the secondary emissive surfaces thereof to be multiplied.

Image intensifiers have a special application in battlefield environments when it is desired to view dimly-illuminated targets. The effect of interference, either deliberate or unintentional, from either steady state or periodic sources, may be reduced by gating the image intensifier tube selectively, i.e. cutting "off" the electron image for selected periods of time. More specifically, interference from steady state sources of light may be reduced by operating the image intensifier tube at a low duty cycle ratio in synchrony with a pulsed illuminator. Alternatively, a suitable source of radiation such as a YAG laser or a GaAs semiconductor laser illuminator may be periodically energized; after a period dependent upon target range, the image intensifier is turned "on" or range gated to sense the reflected illumination from a target at that particular range. In this manner, the effect of laser back scatter may be reduced. Typically, such gated image intensifiers may operate at a relatively low duty cycle of approximately 0.1 percent, thereby rejecting a substantial portion of the objectional ambient illumination.

Considering the micro-channel plate intensifier device in more detail, such an image intensifier may be considered as being divided into two sections with a common boundary at the input or first electrode of the micro-channel plate. The micro-channel plate, as referred to above, has first and second electrodes across which an accelerating voltage is applied. In the front section of the device, an electron lens is provided to focus the electrons emitted from the photocathode onto the input or first electrode of the micro-channel plate. The major part of the electron gain is achieved in the second or back portion of the device, where the electrons entering the channels of the micro-channel plate cause secondary electrons to be emitted from the interior surfaces of the channels. In addition to this electron gain, there is a strong accelerating potential imposed between the output electrode of the micro-channel plate and the phosphorous screen. The voltages applied to the electron optics of the front section are critical; even slight variations in these voltages will

cause distortion in the image displayed upon the phosphorous screen. Therefore, it is necessary to reference all voltages in the front section with regard to the voltage applied to the input electrode of the micro-channel plate. In contrast, variations in the voltages applied to the various elements of the second section of the device effect only the brightness of the image displayed upon the phosphorous screen and the tolerance for these voltages is much greater.

Image intensifier tubes employing micro-channel plates are subject to saturation in the displayed output image when the intensity of the output image exceeds a few foot lamberts. Operation of the micro-channel plate image intensifier in the saturated region causes the gain within the bright areas of the displayed image to be significantly lower than that of the dark areas, thereby destroying image contrast. Further, as the current density developed within the micro-channel plate increases, there is an increasing intensity of outgasing due to the release of trapped gases in the secondary emissive material. The release of trapped gases tends to coat the various other elements within the image intensifier tube to thereby cause irrepairable reduction in the gain and photocathode sensitivity. The rate of outgasing is dependent upon the current density developed within the micro-channel plate and is a major limitation to the life of such tubes.

The use of an automatic brightness control prevents the saturation of the displayed image by limiting the acceleration voltage imposed across the micro-channel plate. By so limiting the accelerating voltage, the current density developed in the micro-channel plate is also limited, thereby reducing the rate of outgasing and prolonging the life of this device. With regard to FIG. **1** of the drawings, there is shown a wafer-type, image intensifier device **10** of the prior art employing a micro-channel plate (MCP) **20** in which a conventional automatic brightness control is employed. More specifically, there is shown within an envelope **12**, a photocathode element **14** comprising a transparent, electrically conductive layer **18** upon which there is disposed layer **16** of a suitable photoemissive material for generating an electron image in response to the incident radiation image. The photocathode **14** is disposed in close proximity to the first electrode **24** of the MCP **20** to ensure accurate focusing of the electron image into the plurality of passages **22** of the MCP **20.** As will be explained later, a variable potential is applied between the first electrode **24** and the second electrode **26** of the MCP **20** to thereby control the accelerating voltage and thereby the gain of the MCP **20.** The multiplied image is directed onto the phosphorous screen **28** to be visually displayed thereby. As shown in FIG. **1,** the conventional automatic brightness control includes a sensing resistor **38** coupled to the output electrode **26** to monitor the current of the multiplied electron image directed onto the phosphorous screen **28.** Typically, when the phosphorous screen current exceeds about 50 nanoamps, the automatic brightness control will reduce the voltage applied between the electrodes **24** and **26** of the MCP **20.** In particular, the voltage developed across the sensing resistor **38** is applied to a variable frequency oscillator **32,** the frequency of whose output signal is dependent upon the input voltage developed across the resistor **38.** The output of the oscillator **32** is applied, in turn, to an AC/DC converter **30,** the amplitude of whose output signal is dependent upon the

signal derived from the oscillator **32.** Thus, as the potential developed across the resistor **38** increases, the DC voltage applied between the electrons **24** and **26** decreases to thereby limit the current of the electron image directed onto the phosphorous screen **28.**

The output electrode **26** of the MCP **20** is held near ground because the sensing circuit including the sensing resistor **38** is a low voltage device and because electrical interference problems arise if the sensing resistor **38** is allowed to float. When the output electrode **36** of the MCP is held near ground, the voltage developed upon the input electrode **24** of the MCP **20** varies with respect to ground as the automatic brightness control circuit, described above, compensates the gain by varying the voltage disposed across the MCP **20.** To maintain proper focus, the potential applied to the photocathode **14** of the wafer device shown in FIG. **1,** is allowed to float with respect to the potential applied to the input electrode **24** of the MCP **20.** An inverter tube, as will be described later, is very similar to the device shown in FIG. **1,** further including accelerating electrodes disposed between the photocathode element and the input electrode of the MCP **20.** In conventional operation of the automatic brightness control, it is understood that the potential applied to these electrodes would also be floated with respect to the potential applied to the input electrode of the micro-channel plate. To complete the description of the circuitry shown in FIG. **1,** a fixed oscillator **36** generates a signal of a substantially fixed frequency, which is applied to an AC/DC converter **34** for applying a substantially fixed voltage to the phosphorous screen **28.**

Conventional automatic brightness control circuits as described above have been satisfactory for steady state operation, but may not be used satisfactorily with an image intensifier device that is gated. In order to gate a wafer device as described above with regard to FIG. **1,** or an inverter device as will be described with respect to FIG. **2,** the gradient of the voltage field established between the photocathode element and the micro-channel plate is reversed, to thereby repel the electron image emitted by the photocathode. Typically, in inverter tubes employing additional focusing electrodes, the potential change required to cut "off" or repel the electron image generated by the photocathode element, is in the order of 1,000–2,000 volts and in typical systems, peak currents are from 1–2 amps. More particularly, the gating voltage typically is applied to the photocathode element, and in order to turn "off" the electron image, the potential applied thereto would be changed from approximately −2,000 volts to −500 volts in a period of approximately 50 nanoseconds. Wafer tubes characteristically require lower potential change, but have higher capacitances with peak currents of between 1–2 amperes in typical gating applications.

The proper gating potentials like the steady state potentials, should be reference to the input electrode **24** of the MCP **20.** Unfortunately, the voltage applied to the input electrode **24** of the prior art image intensifier varies under the control of the automatic brightness control, with the output electrode **26** being held at ground. It has been shown experimentally that it is not practical to float the gating circuit or supply because of leakage current problems primarily associated with the micro-channel plate. For example, the current of the phosphorous screen **28** is approximately 50 nanoamps; under such conditions where 5 nanoamps of leakage current is permitted and 500 volts is applied across the electrodes **24** and **26** of the MCP **20,** 10 gigaohms of isolation would be required. To provide such isolation would require an inordinate amount of insulating material, possibly in the form of a potting insulating medium, thus making the resulting assembly inappropriate for portable applications. Even if it were possible to achieve the desired isolation, it would be undesirable to permit the external gating circuit to float above ground by the amount of the varying MCP voltage, because of problems involved in packaging the gating circuit itself. An alternative to floating the gating circuit would be to connect the input electrode **24** of the MCP **20** to ground and to permit the second or back section of the device to float. This approach is considered to be unacceptable since it is difficult in field environments to ensure that the battery supply will be kept sufficiently dry to maintain proper insulation with respect to ground. Further, the leakage current developed through the micro-channel plate **20** imposes undesired signals upon the sensing resistor **38,** which would disturb the normal operation of the automatic brightness control.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to facilitate the selective gating of an electron image generated within an image intensifier tube, while permitting a variable potential to be applied across the micro-channel plate of such a tube by an automatic brightness control.

It is a further object of this invention to provide an image intensifying tube incorporating a micro-channel plate of relatively light weight suitable for portable applications in a rugged environment, while incorporating therein the features of gating and automatic brightness control.

In accordance with these and other objects, the subject invention includes an image intensifying tube including a photocathode element for generating an electron image in response to an input radiation image. The electron image is directed onto a micro-channel plate including first and second electrodes between which are disposed a plurality of passages whose surfaces are formed of a secondary emissive material. The electron image is multiplied by repeated bombardment of the secondary emissive material and the resulting multiplied electron image is directed onto a phosphorous screen to be displayed as an intensified visual image. In accordance with teachings of this invention, a sensing element, e.g. a resistor, is associated with the second or output electrode of the micro-channel plate for sensing the current of the multiplied electron image to thereby control a first, variable oscillator, the frequency of whose output signal is dependent upon the sensed signal. In turn, an AC/DC converter is responsive to the output signal of the variable oscillator to provide a voltage between the first and second electrodes of the micro-channel plate inverse to the voltage sensed by the resistor. A gating circuit is connected between ground and the photocathode element for selectively gating or turning "off" the electron image by applying a more positive voltage to the photocathode element. Significantly, the potential supply for the phosphorous screen is made of first and second sections. The first section comprises an AC/DC converter capacitively coupled to the output of the variable oscillator for providing a

variable voltage between the second electrode of the micro-channel plate and the phosphorous screen, substantially equal to that variable potential placed between the first and second electrodes of the micro-channel plate. The second section of the phorphorous screen supply comprises a fixed oscillator for providing an output signal substantially of a fixed frequency, which is applied to a third AC/DC converter. The substantially constant output voltage derived from the third AC/DC converter and the varying voltage derived from the second AC/DC converter, are applied to the phosphorous screen, whereby the voltage between the output electrode of the micro-channel plate and the phosphorous screen is maintained substantially constant.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will become more apparent by referring to the following detailed description and accompanying drawings, in which:

FIG. 1 is a schematic diagram of an image intensifier tube coupled in circuit with an automatic brightness control circuit of the prior art; and

FIG. 2 is a schematic diagram of an image intensifier tube coupled with a gating circuit and an automatic brightness control circuit in accordance with the teachings of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

With regard to the drawings and in particular to FIG. 2, there is shown an illustrative embodiment of an image intensifier device **100**, including an envelope **112** in which there is disposed a micro-channel plate (MCP) **120**. Illustratively, the MCP **120** includes first and second electrodes **124** and **126** made of a suitable electrically conductive material such as aluminum and disposed on each face of the MCP **120**. The MCP **120** includes a plurality of openings or passages **122** disposed therethrough from the first electrode **124** to the second electrode **126**; the passages **122** are made of a suitable secondary emissive material such as an alkali metal, to present surfaces of a secondary emissive property. For a more complete description of the micro-channel plate **120**, reference is made to *Electro-Optical Photography at Low Illumination Levels*, Harold V. Soule, John Wilby and Sons, 1968, Section 3.6. Further, a photocathode element **114** is disposed to receive a radiation image to be intensified, and includes a transparent, electrically conductive layer **118**, made of a suitable material such as tin oxide (SnO_2), upon which there is disposed a layer **116** of a suitable photo-emissive material such as cesium. The photocathode element **114** generates an electron image corresponding to the incident radiation image, to be focused and inverted by an electron lens formed of electrodes **142** and **144** onto the micro-channel plate **120**. Typically, potentials of 0 volts and −1,800 volts may be applied respectively to the electrodes **142** and **144** to focus the electron image onto the input electrode **124** of the MCP **120**. As described above, the electron image is multiplied as the electrons repeatedly bombard the surfaces of the passages **122**. The multiplied electron image is directed from the MCP **120** onto the phosphorous screen **128** to be displayed as an intensified visual image. Though an image intensifier device of the inverter tube type has been described with regard to FIG. **2**, it may be understood that the wafer-type tube, as illustrated in FIG. **1**, may also be used with the gating circuit and automatic brightness control as taught by this invention.

Significantly, the input electrode **124** is coupled to ground and a gating circuit **140** is connected between ground and the electrically conductive layer **118** of the photocathode **114** to selectively apply gating potentials to turn "on" and "off" the electron image to reduce the effects of interfering radiation, as described above. Illustratively, the gating circuit **140** applies in the "on" mode a potential of approximately 2,000 volts negative with respect to the input electrode **124**, to accelerate the electron image from the photocathode element **114** onto the MCP **120**, and in its blanking or turned "off" mode, applies a potential of approximately 500 volts negative to cause thereby the electron image to be repelled before reaching the input electrode **124** of the MCP **120**.

The automatic brightness control, in accordance with the teachings of this invention, includes a first, variable oscillator **132**, the frequency of whose output signal is dependent upon the current of the electron image and whose output signal is applied to an AC/DC converter **130**. The DC output derived from the AC/DC converter **130** is inversely proportional to the current of the electron image and is applied between the input electrode **124** and the output electrode **126** to control the acceleration of the electron image through the passages **122**. A sensing resistor **142** is associated with the second electrode **126** to develop thereacross a potential dependent upon the current of the multiplied electron image, which in turn serves to control the frequency of the variable oscillator **132**.

In accordance with the teachings of this invention, the power supply for the phosphorous screen **128** is divided into two parts, for maintaining the potential between the second electrode **126** and the phosphorous screen **128** substantially constant. More specifically, the first part of the power supply comprises a second AC/DC converter **138** capacitively coupled to and driven by the variable oscillator **132** so that the DC output derived from the AC/DC converter **138** is substantially equal to that potential applied between the first and second electrodes **124** and **126** of the MCP **120**. The second part of the phosphorous screen power supply includes a second, fixed oscillator **136**, the frequency of whose output signal is substantially constant. The output of the fixed oscillator **136** is capacitively coupled to a third AC/DC converter **134** whose DC output signal is connected to the phosphorous screen **128**. Thus, the potential applied to the phosphorous screen **128** floats so that the potential difference between the second electrode **126** and the phosphorous screen **128** is substantially constant. As shown in FIG. **2**, AC coupling of the screen supply keeps the sensing resistor **142** near ground. By driving one of the screen supplies with the variable oscillator **132**, the phosphorous screen voltage is made to follow the potential applied to the second electrode **126** of the MCP **120**, thereby maintaining a substantially equal accelerating potential between the second electrode **126** and the phosphorous screen **128**. Though in practice the potential supplied to the second electrode **126** and to the phosphorous screen **128** will not follow each other perfectly, the tolerances on the potential applied to these

elements has been shown experimentally to be fairly large, and the tracking accuracy provided by the described system should exceed the required tolerances.

Thus, in summary, there has been shown an image intensifier device incorporating a high gain microchannel plate in combination with a gating circuit for selectively turning "on" and "off" the electron image directed thereon, and an automatic brightness control for varying the accelerating potential applied across the microchannel plate. Significantly, the potential supply interposed between the output electrode of the microchannel plate and the phosphorous screen is composed of two sections, the first section providing a voltage corresponding to that derived from the automatic brightness control and the second section providing a substantially constant potential, the sum of which is applied to the phosphorous screen.

Numerous changes may be made in the above-described apparatus and the different embodiments of the invention may be made without departing from the spirit thereof; therefore, it is intended that all matter contained in the foregoing description and in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An image intensifier device comprising:

a. photocathode means responsive to incident radiation image for generating a corresponding electron image;

b. electron multiplying means for multiplying the electron image derived from said photocathode means, said electron multiplying means including an input electrode and an output electrode;

c. display means responsive to the multiplied electron image for providing a visual radiation image corresponding thereto;

d. gating means interconnected between said input electrode and said photocathode means for selectively permitting the flow of electrons from said photocathode means to be directed onto said electron multiplying means;

e. brightness control means responsive to the current of the multiplied electron image directed onto said display means for varying the potential applied between said input electrode and said output electrode to prevent substantially the saturation of said display means; and

f. display supply means responsive to the variable voltage applied between said input and output electrodes for applying a selectively variable voltage to said display means such that a substantially constant potential is maintained between said output electrode and said display means.

2. An image intensifier device as claimed in claim **1**, wherein said electron multiplying means comprises means for defining a plurality of passages therethrough between said input electrode and said output electrode, each of said passages having a surface of a secondary electron emissive material.

3. An image intensifier device comprising:

a. photocathode means responsive to incident radiation image for generating a corresponding electron image;

b. electron multiplying means for multiplying the electron image derived from said photocathode means, said electron multiplying means including an input electrode and an output electrode;

c. display means responsive to the multiplied electron image for providing a visual radiation image corresponding thereto;

d. gating means interconnected between said input electrode and said photocathode means for selectively permitting the flow of electrons from said photocathode means to be directed onto said electron multiplying means;

e. brightness control means responsive to the current of the multiplied electron image directed onto said display means for varying the potential applied between said input electrode and said output electrode to prevent substantially the saturation of said display means; and

f. display supply means responsive to the variable voltage applied between said input and output electrodes for applying a selectively variable voltage to said display means such that a substantially constant potential is maintained between said output electrode and said display means, said display supply means including a first part responsive to the variable potential applied between said input and output electrodes for producing a first signal corresponding thereto, and a second part for producing a second signal of substantially fixed magnitude, and means for applying the first and second voltages to said display means to provide a substantially constant potential between said output electrode and said display means.

4. An image intensifier device as claimed in claim **3**, wherein said brightness control means includes a sensing resistor responsive to the current level developed in said display means in response to the incident multiplied electron image for providing a signal indicative thereof; a first, variable oscillator responsive to the aforementioned signal for generating an output signal whose frequency corresponds thereto; and a first AC/DC converter circuit responsive to the output signal of said first, variable oscillator for applying a voltage between said input electrode and said output electrode varying inversely to the signal derived from said sensing resistor.

5. An image intensifier device as claimed in claim **4**, wherein said display supply means includes a second AC/DC converter responsive to the output signal of said first, variable oscillator for providing a DC output signal corresponding to the output signal applied between said input electrode and said output electrode.

6. An image intensifier device as claimed in claim **5**, wherein said display supply means further includes a second, fixed oscillator for providing an output signal of substantially fixed frequency and a third AC/DC converter responsive to the output signal of said second, fixed oscillator for providing a DC output signal of substantially fixed magnitude, and means for summing the output signals of said second AC/DC converter and said third AC/DC converter and for applying the summed signal to said display means to provide a substantially constant voltage between said output electrode and said display means.

7. Apparatus as claimed in claim **4**, wherein said first electrode is connected to ground and said second electrode is coupled through said sensing resistor to ground.

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