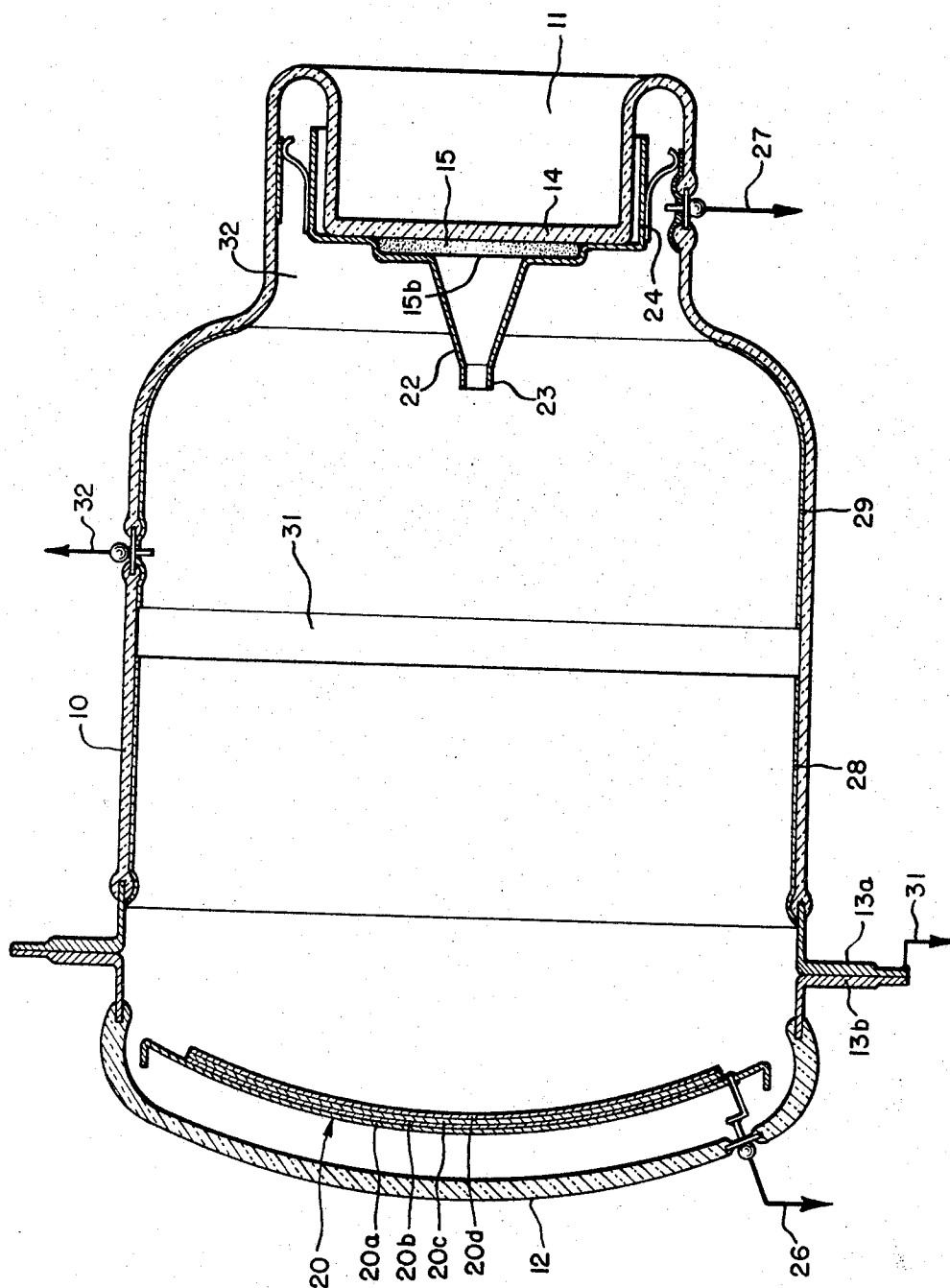


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IMAGE INTENSIFIER TUBE WITH SHADING COMPENSATION

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2 Claims

ABSTRACT OF THE DISCLOSURE

An improved electron optical system is described for an image intensifier tube. In the preferred embodiment, means for alleviating defects in the output image in the form of uneven illumination and/or peripheral distortion, commonly referred to as "shading," are provided by coating the interior wall surface of a cylindrical image intensifier tube with a thin conductive band which is axially split approximately at its center. The two wall electrodes thus formed have identical diameters which are greater than the diameter of the photoemissive cathode and have a total width approximately equal to one-half of the length of the tube. The potential gradient at the photo-cathode surface is adjusted by controlling the potentials applied to the wall electrodes to counteract asymmetries of the system resulting from mechanical misalignment, stray magnetic fields, undesired electrostatic fields, or the like and thereby optimize the brightness distribution and peripheral resolution of the output image.

The present invention relates to image converters and more particularly is directed to a new and improved image intensifier of the type which is responsive to X-rays, gamma-rays, neutrons or the like.

One widely known type of X-ray image intensifier consists essentially of an electron-optical system comprising a photo-emissive cathode responsive to incident radiation of a particular wavelength to generate an electron image which is directed or propagated by the use of a suitable electric field to a fluorescent viewing screen where the electron image is converted to a visible reproduction constituting a replica of the original image projected on the photo-emissive cathode. Many modern X-ray image intensifiers also employ electron-optical elements intermediate the photo-emissive cathode and the fluorescent viewing screen for the purpose of accelerating the electrons to the screen and focusing them thereon with or without an accompanying variation from original image size while minimizing distortion in the reproduced image. A typical electron-optical system includes an anode positioned adjacent the viewing screen and having an aperture through which electrons emitted by the photo-cathode may be directed to impinge upon the viewing screen. A high voltage is imposed upon the anode to establish the necessary accelerating field, and a suitably shaped focusing electrode is interposed between the anode and the photo-cathode to form, in conjunction with the anode, a suitable electron-optical lens.

It is desirable, in such image intensifiers to minimize the distance separating the cathode and anode to thereby obtain a more compact, and perhaps lighter overall package. This objective requires the image intensifier to have a strongly convergent electron lens arrangement. In the simple triode X-ray image intensifier above described having a cathode, a focusing electrode and an anode, electron lens convergence is increased for fixed anode potential by reducing the potential applied to the focusing electrode. However, this correspondingly reduces the potential gradient at the photo-cathode surface, particularly at the peripheral portions of the cathode, eventually permit-

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ting an electron space charge to form in the vicinity of the cathode surface. The photoemission is then dependent upon the potential gradient in front of the photo-cathode. As the potential gradient decreases with increasing radial spacing, the illumination of the output image will decrease with increasing radial spacing. Further, a local change in the potential gradient in front of the photo-cathode, which might be due to a local deviation of the photo-cathode surface from the prescribed spherical or aspherical form, manifests itself in an uneven illumination of the output image. These defects are commonly called "shading" and may appear in the form of a ring shadow or half-moon shadow on the viewing screen. In the latter instance, stray magnetic fields or undesired electrostatic field components due to asymmetries in the system are responsible for the asymmetric form of this effect.

Various structural arrangements are known to enhance, without material distortion or increase in the number of electrodes, the convergence of an electron lens. For instance, as will be pointed out in more detail herein, the cathode may assume a predetermined aspherical configuration and/or the anode may be constructed in the shape of a centrally apertured flat disc. These structures may be used independently or collectively in a tube if consistent with other extrinsic design criteria. Any electron-optical lens of the design described above, namely, consisting of a spherical or aspherical photo-cathode, a single cylindrical focus electrode, and a suitably shaped anode has the inherent disadvantage that the potential gradient in front of the photo-cathode and the convergence of the lens is determined by the potential of the cylindrical focus electrode, all other parameters kept constant. It is desirable to provide for an independent adjustment of the potential gradient in front of the photo-cathode and the lens convergence. This can be achieved by additional focusing electrodes of a substantially smaller diameter than either the primary focusing electrode or cathode, and supported in relatively close proximity to the anode to form, in conjunction with the first focus electrode and anode, a second convergent electron lens, as known to the art. In large tubes, that is 5 inches in diameter or larger, the weight of such a second cylindrical electrode and its associated supporting structure undesirably increases the weight of the tube and also adds significantly to both the cost and labor required for production of small or large tubes.

It is accordingly an object of the present invention to provide a new and improved image intensifier having an electron-optical system which overcomes the aforementioned limitations of the prior art.

It is a further object of the present invention to provide a new and improved image intensifier of relatively short longitudinal dimension which is capable of construction in an economical and simple manner.

It is a more specific object of the present invention to provide an image intensifier of a novel and compact design which substantially eliminates shading in the viewed image.

An image intensifier constructed in accordance with the invention is enclosed within a generally cylindrical envelope and comprises an electron-optical system including a photo-emissive cathode of a predetermined diameter disposed transversely to the axis of an electron-optical path along which electrons emitted from the cathode are projected. The electron-optical system further includes an anode disposed transversely and substantially coaxially with the path and having a centrally located aperture of a diameter substantially smaller than the cathode diameter for admitting electrons to an image plane having a diameter larger than that of the anode aperture but smaller than that of the cathode and spaced from the cathode beyond the anode aperture, and a pair of electrically independent

generally cylindrical focus electrodes disposed about the axis intermediate the anode and cathode and having substantially identical maximum diameters each larger than the cathode diameter.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, the single figure of which illustrates an X-ray image intensifier embodying the present invention.

The image intensifier shown in the drawing comprises a generally cylindrical glass envelope section 10 having one end closure in the form of a re-entrant press 11 and an opposite end closure comprising a substantially spherical glass section 12 of a diameter approximating that of envelope section 10. Envelope sections 10 and 12 are presealed around their entire peripheries to respective metal flanges 13a and 13b which, in turn, are joined by arc welding or the like after envelope sections 10 and 12 have been separately processed. Re-entrant section 11 is closed by a transparent glass plate 14 on the inside of which a suitable fluorescent viewing screen 15 of silver activated zinc cadmium sulfide or the like is provided. Screen 15 is preferably aluminized or otherwise provided with an electrically conductive and light reflecting metallic backing layer 15b which is sufficiently thin as to be pervious to impinging electrons. An electron-optical system within the tube causes electrons to impinge on the image plane formed by screen 15 in order to synthesize a visible image thereon.

The electron-optical system of the image intensifier includes a photo-sensitive cathode structure 20 which is generally referred to in the art as a composite multilayer pickup screen. This cathode structure is fixedly supported within section 12 of the envelope and may be generally spherical in configuration, although it is preferred herein that the cathode assume a predetermined aspherical configuration to improve convergence and to minimize radical focusing variations in the projected image. Further advantages and structural dimensions of a particularly suitable aspherical cathode structure are disclosed and claimed in Patent 2,974,244 to Wilfrid F. Niklas and assigned to the same assignee as the present invention. Cathode 20 is positioned transversely of and substantially coaxially with both the tube and the axis of the electron-optical paths along which electrons emitted from the cathode are projected towards viewing screen 15. The cathode surface as seen from viewing screen 15 is concave and comprises a support or base member 20a which is transparent to incident radiation of the type to which the image intensifier is intended to respond. While devices of the type under consideration may be constructed to selectively respond to radiation of different wavelengths, the device illustrated will be assumed to be an X-ray image intensifier. Hence, the face portion of envelope section 12 as well as cathode base member 20a are constructed of material that is transparent to X-rays, and in this regard envelope section 12 may be of glass and support 20a may be formed of aluminum. The thickness of support 20a is selected to give the required mechanical rigidity to the structure but otherwise the thickness should be of minimal dimension to increase the sensitivity of the device to incident radiation. Also, X-ray admitting window 12 may be of uniform thickness, but preferably is of a non-uniform thickness, as shown, in order that the distance through the glass of a divergent X-ray beam remains the same length whether the beam penetrates the window at the axis or in the peripheral area. Such a window section is disclosed and claimed in Patent 2,955,219 to Wilfrid F. Niklas and assigned to the same assignee as the present invention.

Deposited immediately upon supporting member 20a is an X-ray sensitive phosphor layer 20b such as silver

activated zinc cadmium sulfide or the like embedded in a suitable silicone resin. A barrier layer 20c which may be of aluminum oxide is superposed over phosphor layer 20b and a photo-emissive layer 20d is placed over the barrier layer. The photo-emissive layer is generally an antimony-cesium composition and constitutes the electron emitting surface of the cathode structure. This component of the image intensifier may be entirely conventional both as to its composition and method of manufacture; it is preferred, although not in any respect essential to the present invention, that the screen be of a predetermined aspherical shape as disclosed in the aforementioned Niklas Patent 2,974,244.

An anode 22 of the electron-optical system is likewise disposed transversely and substantially coaxially with the tube and electron-optical axis. The anode structure shown is provided with a cylindrical cap or terminating portion 23 having an open top section to permit access for electrons traversing the electron-optical system to an image plane which is normal to the tube axis and spaced from the cathode surface beyond the anode aperture. Anode 22 extends in a generally frusto-conical fashion from apertured cap 23 to viewing screen 15 and is electrically connected thereto to maintain the screen at the same electrical potential as the anode. In image intensifiers wherein a strongly convergent lens effect is desired with image minification values generally in the range of 3 to 5, anode 22 may be comprised of a flat, plate-like face which is centrally apertured. Such a construction is disclosed and claimed in Patent 3,300,668 issued to Wilfrid F. Niklas and assigned to the same assignee as the present invention. In the illustrated tube, a minification in the order of 10 is desired, hence the anode construction shown is preferred. At any rate, anode 22 is mechanically supported within the envelope by its physical connection to screen 15 and by a metal support bracket 24.

In accordance with the invention, the electron-optical system of the image intensifier is further provided with a pair of electrically independent generally cylindrical focus electrodes 28 and 29 disposed about the electron-optical axis of the tube at locations intermediate anode 22 and cathode 20 and constructed to have substantially identical maximum diameters each larger than the diameter of cathode 20. Preferably, focus electrodes 28 and 29 comprise a pair of axially spaced conductive bands supported on the interior sidewalls of envelope section 10. Bands 28 and 29 may comprise a metal coating such as aluminum which is evaporated after masking of appropriate portions of the envelope such as segment 31 of envelope 10 which separates the focusing electrodes and re-entrant portion 32 of the tube. In most environments, segment 31 preferably is left uncoated, glass envelope section 10 serving as the insulative medium separating electrodes 28 and 29. To further enhance operation of the tube, but in a manner independent of the present invention, it is preferred that the interior sidewalls of re-entrant portion 32 be provided with a semiconductive coating of the type disclosed and claimed in Patent 3,026,437 to Wilfrid F. Niklas and assigned to the same assignee as the present invention.

Means of conventional construction are relied upon to apply the desired operating potentials to the cathode and the anode. The connections from these means to appropriate voltage sources (not shown) are schematically designed in the drawing by the respective construction lines 26 and 27 terminating in arrow heads. Similar conventional means are used to apply appropriate operating potentials to first focus electrode 28 and second focus electrode 29 and these means are symbolically indicated to be coupled to conventional voltage sources (not shown) by respective arrows 31 and 32.

In structural effect, focus electrodes 28 and 29 merely represent a single substantially conventional focus electrode which has been split or separated at an intermediate location. The exact location at which the electrode is split

is not critical, subject only to the limitation that each section must be of sufficient width to accomplish its respective intended function. As is apparent, the new structure thus formed adds nothing to the weight of the tube and little, if any, to the cost or time required for manufacture thereof, but it will be appreciated from an analysis of the operation of this tube given hereinafter that significant functional advantages result therefrom. Specifically, and as previously mentioned herein, a sufficiently high potential gradient must exist at all points on the surface of cathode 20 to draw off all electrons emitted as a result of impinging radiation. Thus a potential adequate for this purpose is applied to the first focus electrode 28 while a different potential, as required to establish in conjunction with anode 22 a strongly convergent electron lens necessary for proper focusing of the electron image on the image plane formed by phosphor viewing screen 15, is applied to focus electrode 29.

One embodiment of the present invention was operated satisfactorily with an adjustable potential supply of 0-400 volts for first focus electrode 28 and an adjustable supply of 0-800 volts for second focus electrode 29. In this structure, photocathode 20 was grounded and anode 22 operated at 27,000 volts. The exact potentials applied to focus electrodes 28 and 29 are empirically determined for each tube by visual observation of the image and are effectively varied to accommodate particular operating conditions. Since focusing in the described arrangement is achieved independently of optimizing the brightness, distribution across the output image, the system is less sensitive to mechanical misalignment or stray magnetic fields than comparable triode-type image intensifiers. It is also possible by use of the structure of the invention to change output image size by as much as 8 to 10 percent without materially affecting focus. It has been observed that the curvature of the electron-optical plane is reduced with a corresponding improvement in peripheral image resolution.

Further by way of illustration and in no sense by way of limitation, one physical embodiment of the inventive structure found to provide all of the advantages noted above employed the following dimensional parameters:

	Inches
Maximum diameter of useful cathode surface ----	6
Maximum diameter of focus electrodes 28, 29 --	7
Length of focus electrode 28 -----	2 $\frac{5}{8}$
Width of separation band 31 -----	$\frac{3}{8}$
Distance from center of cathode screen 20 to aperture of anode 22 -----	7 $\frac{11}{16}$
Distance from aperture of anode 22 to viewing screen 15 -----	1 $\frac{5}{16}$
Diameter of output image on viewing screen 15 --	$\frac{5}{8}$

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and, therefore, the aim in the appended claims

is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. In an image intensifier system of the type enclosed within a generally cylindrical envelope and having an electron-optical system including a photo-emissive cathode of a predetermined diameter disposed transversely with respect to the axis of an electron-optical path along which electrons emitted from said cathode are projected, an anode disposed substantially coaxially with said path and further having a centrally located aperture of a diameter substantially smaller than said determined cathode diameter for admitting said electrons in order to form a focused image on a phosphor image screen having a diameter larger than that of said anode aperture but smaller than that of said cathode and spaced from said cathode beyond said anode aperture, said image being subject to defects in the form of uneven illumination and peripheral distortion resulting from asymmetries in said system:

means for optimizing image brightness distribution and peripheral image resolution, comprising a pair of electrically independent generally cylindrical electrodes consisting of electrically conductive bands deposited on the interior sidewall of said envelope and symmetrically disposed about said axis intermediate said anode and said cathode and having substantially identical maximum diameters each larger than said cathode diameter and respectively operable at different operating potentials, for permitting adjustment of the potential gradient at said cathode without materially affecting image focus.

2. The combination as defined in claim 1, in which said electrodes have widths approximately equal to each other and substantially equal to one-third of the overall length of said intensifier tube, and the diameter of each of said pair of electrodes is substantially equal to the spacing between said cathode and said anode along said axis.

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