United States Patent

Levin et al.

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[54] **ELECTRON OPTICS FOR A MINIFYING IMAGE TUBE**

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[51] **Int. Cl.** **H01j 31/50**

[58] **Field of Search** ......250/213 VT; 313/82 R, 65 R

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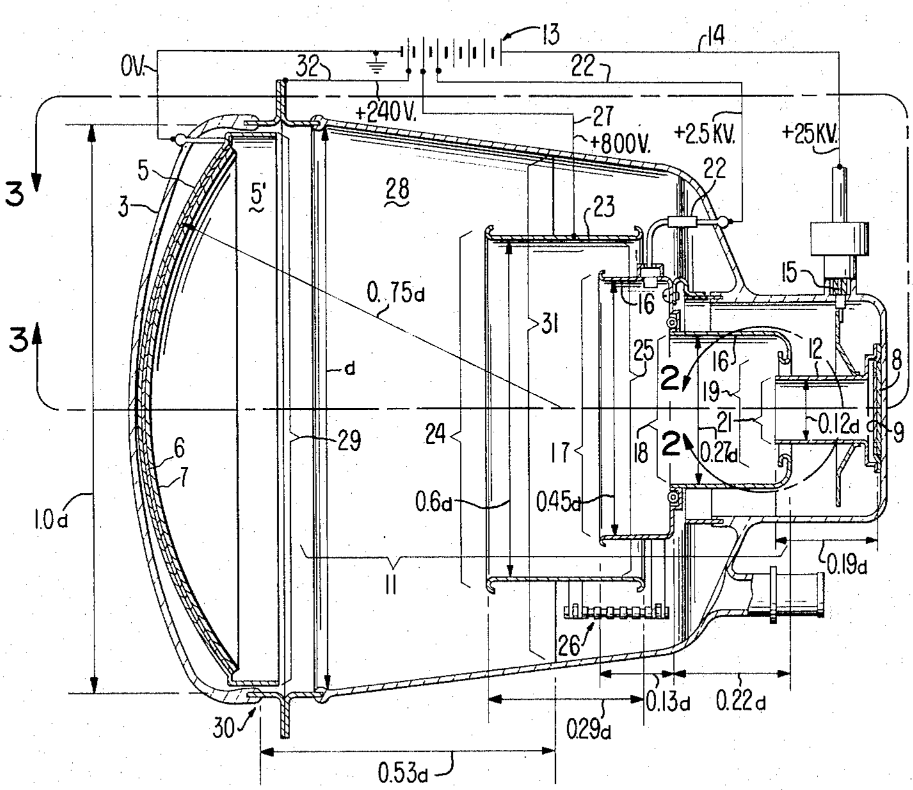
[57] **ABSTRACT**

A minifying image tube, such as an X-ray converter or image intensifier tube, is disclosed employing a curved photocathode for converting a photon image into an electron image. A flat image converter screen is provided for converting the minified electron image into an optical output image. An electrode structure is disposed between the photocathode and the flat converter screen for accelerating and focusing the electron image upon the converter screen. The electrode structure includes a plurality of coaxially aligned axially spaced cylindrical electrodes of decreasing diameter taken in the direction from the photoemitter toward the converter screen. The final or anode electrode projects into a constricted electron exit aperture in the next preceding electrode structure in order to shape the equipotentials at the entrance of the anode such as to obtain uniform resolution of the electrode image focused upon the flat converter screen over substantially the entire area of the converter screen.

4 Claims, 3 Drawing Figures



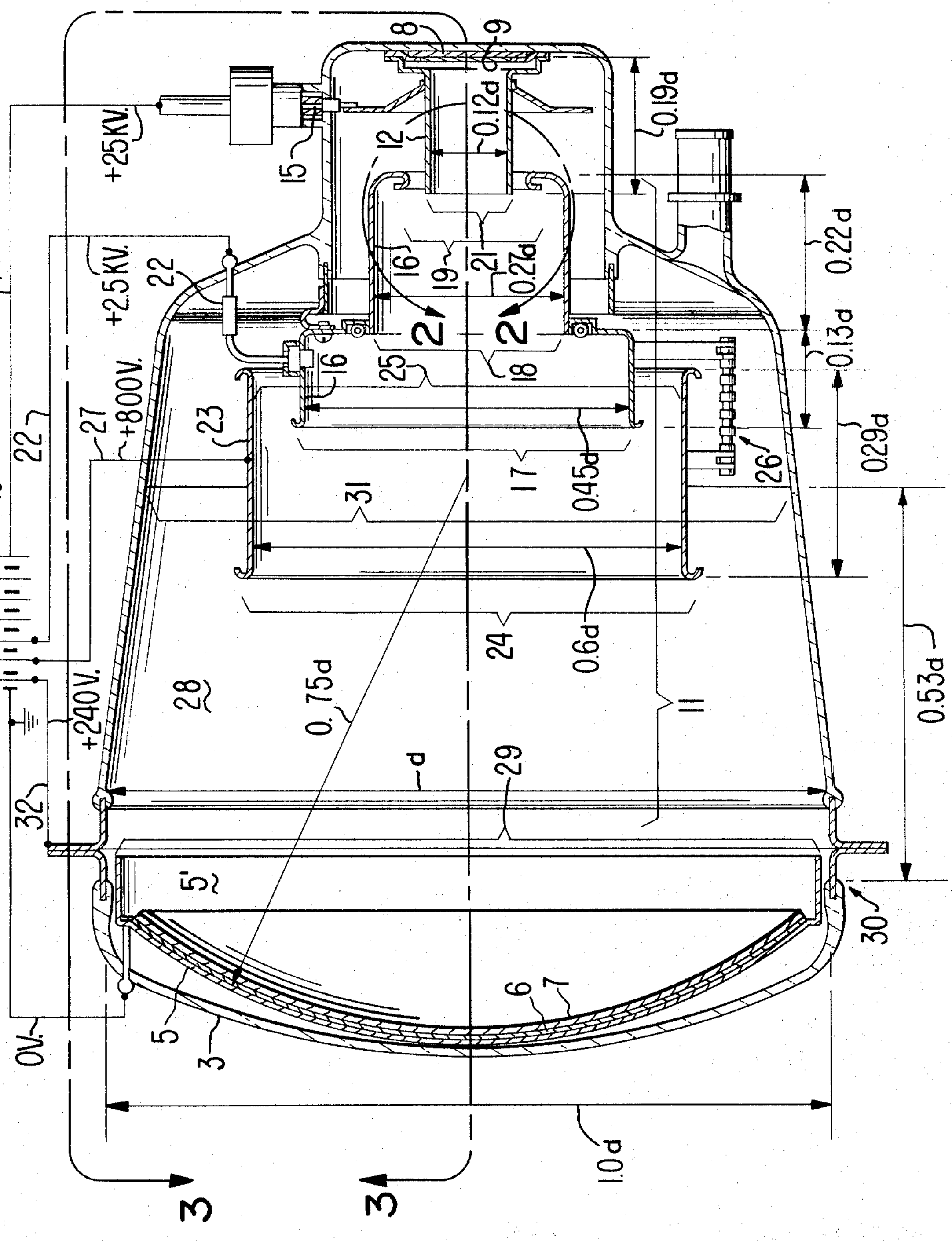


FIG. 1

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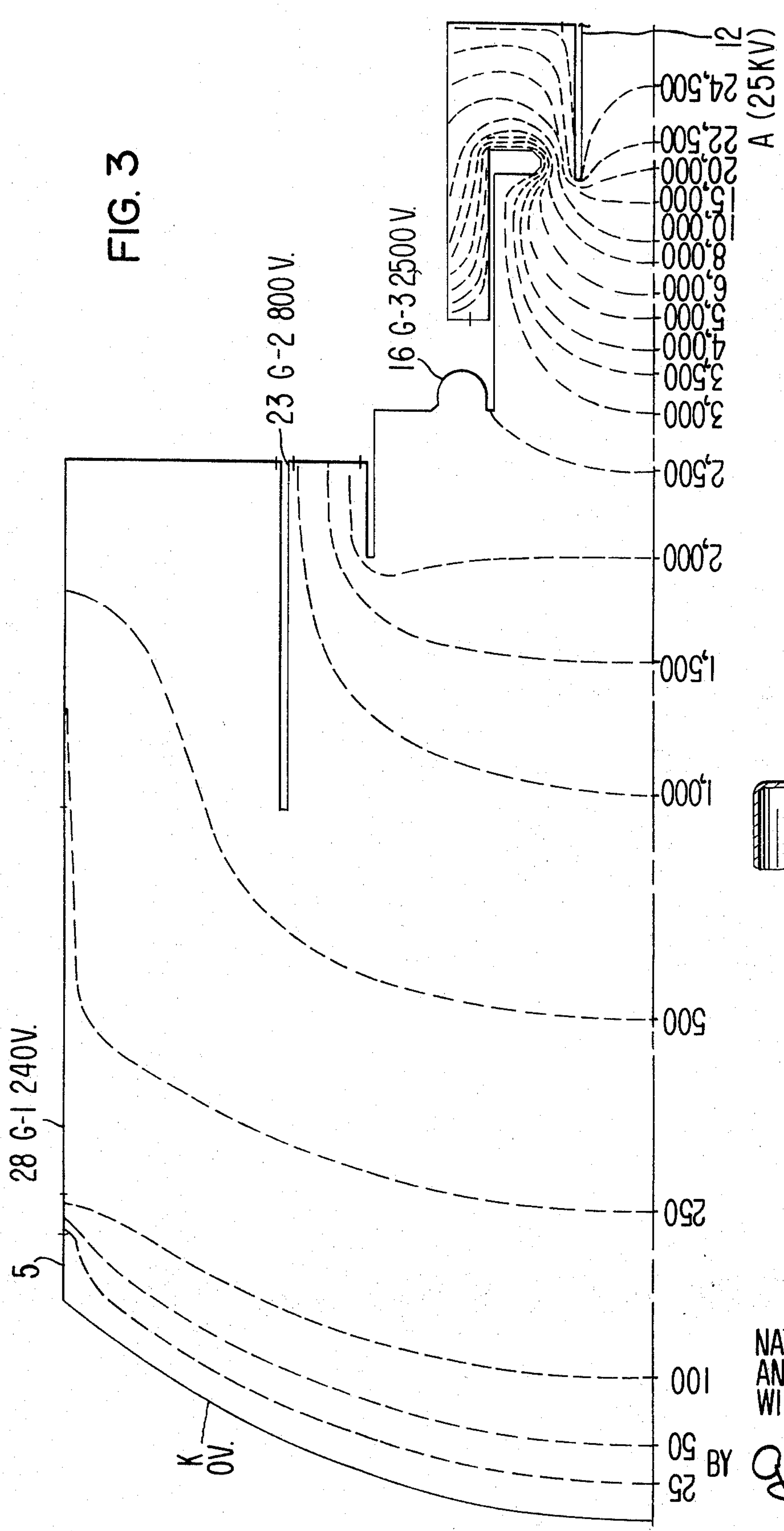
FIG. 3



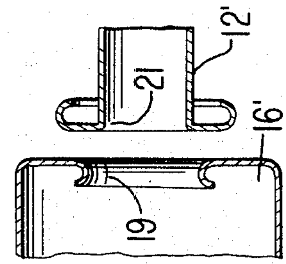


FIG. 2
PRIOR ART

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ELECTRON OPTICS FOR A MINIFYING IMAGE TUBE

DESCRIPTION OF THE PRIOR ART

Heretofore, minifying image tubes, such as image intensifier tubes and X-ray converter tubes, have employed a succession of cylindrical focusing and accelerating electrodes disposed between the curved photocathode and a flat image converter screen. However, in these prior art tubes the final or anode electrode of the smallest diameter had its electron entrance aperture or mouth portion disposed downstream from the exit opening in the next preceding electrode such that an axial gap was created between the upstream end of the anode and the downstream end of the next preceding electrode. This electrode geometry results in distortion of the electron image as focused upon a flat image converter screen such that resolution is degraded near the outer perimeter of the image as compared to the resolution obtained near the center of the image. It is desired to obtain electron optics for such minifying image tubes which will yield a uniformly high resolution over the entire image of the converter screen.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of improved electron optics for a minifying image tube.

One feature of the present invention is the provision, in a minifying image tube, of an electron accelerating and focusing electrode structure including an anode electrode which projects at its upstream end into the exit portion of the next preceding electrode structure, whereby the equipotentials at the mouth of the anode are shaped to obtain near uniform resolution of the electron image focused on a flat converter screen over essentially all parts of the converter screen.

Another feature of the present invention is the same as the preceding feature wherein each of the focusing and accelerating electrodes is cylindrical with the mouth portions of each successively smaller electrode being disposed within the exit portion of the next preceding larger electrode to define a series of convergent electron focusing lenses.

Another feature of the present invention is the same as any one or more of the preceding features wherein the electrode structure upstream from the anode has an exit portion with dimensions constricted substantially relative to the dimensions of its upstream mouth portion.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of a minifying image tube incorporating features of the present invention,

FIG. 2 is an enlarged detail view of a portion of the structure of FIG. 1 delineated by line 2—2 and depicting a prior art electrode structure, and

FIG. 3 is a schematic line diagram of a portion of the structure delineated by line 3—3 of FIG. 1 and depicting the shapes of the equipotentials for the electrode structure of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, there is shown a minifying image tube 1, in this case an X-ray converter tube, incorporating features of the present invention. The minifying image tube 1 includes an evacuable envelope structure 2, as of glass, having an outwardly domed spherical shaped face plate portion 3. A similarly domed conductive electrode structure 5, which is transparent to an X-ray photon image which passes through the face plate 3, is mounted within the domed face plate 3. A scintillator layer 6 is deposited on the inside concave surface of the conductive electrode 5 and a photocathode 7 is deposited over the inside surface of the scintillator layer 6.

X-ray photons passing through an object to be observed, pass through the face plate 3, conductive electrode 5 and are partially absorbed in the scintillator layer 6 to produce an optical photon image corresponding to the X-ray image to be observed. The photon image is partially absorbed in the photocathode 7 to convert the photon optical image into an electron image which is emitted into the evacuated envelope 2 from the photocathode 7.

A flat image converter screen 8, made of a conventional fluorescent material, is disposed at the end of a narrow neck portion of the envelope 2 at the opposite end of the tube 1. A very thin conductive layer 9, as of aluminum, is deposited over the converter screen 8 for applying a uniform electrical potential to the screen 8.

An electrode structure 11 is disposed between the photocathode 7 and the image converter screen 8 for accelerating and focusing the electron images emitted by the photocathode 7 onto the image converter screen 8 where an electron image is converted into an optical image for observation or use. In a typical tube 1, the diameter of the image focused upon the image converter screen 8 is approximately one/tenth of the diameter of the electron image produced from the photocathode 7. Thus, the electrode structure 11 serves to minify the image obtained from the photocathode 7 by a relatively large factor, such as by a factor of 10.

The electrode structure 11 includes a hollow cylindrical anode or fourth focus electrode 12 disposed adjacent the image converter screen 8 and operated at the same potential, as of about 25 kV positive with respect to the cathode, as that applied to the image converter screen 8 via the conductive electrode 9. The electrical potential for the anode 12 is supplied from a source of potential 13 via lead 14 and a feedthrough electrode 15.

A third focus electrode 16 is disposed immediately upstream from said anode electrode 12. The third electrode 16 includes a cylindrical mouth portion 17 which is constricted near its midpoint 18 and further constricted at its downstream exit portion 19. The upstream end or mouth portion 21 of the anode electrode 12 is disposed within the exit opening 19 in the third electrode 16. This geometry approximates that of a two cylinder electron lens and greatly facilitates obtaining uniform resolution of the electron image focused over the entire surface area of the image converter screen **8**. More particularly, with this geometry substantially no degradation of the resolution of the image is obtained from the center of the converter screen **8** toward the outer perimeter of the converter screen **8**. This contrasts markedly with the geometry and resolution obtained in the prior art, as shown in FIG. **2**. In the prior art structure, the electron exit aperture **19** in the third electrode structure **16'** was axially spaced from the electron entrance aperture **21** of the anode electrode **12'**. As a result, the electron optics were less than optimum resulting in a degradation of the resolution of the image obtained from the image converter screen **8** near the outer perimeter of the image.

An operating potential, as of about 2.5 kV positive with respect to cathode, is applied to the third electrode structure **16** via lead **22** which is tapped off the potential source **13**.

A second cylindrical focus electrode structure **23** is disposed upstream of the third electrode **16**. The second electrode structure **23** includes a hollow cylindrical member having an electron entrance aperture **24** at the upstream end thereof and an electron exit aperture **25** at the downstream end thereof. The mouth **17** of the third electrode structure **16** is disposed within the electron exit aperture **25** of the second electrode structure **23** to form a two cylinder electron focusing lens. Electrode **23** is supported from the third electrode **16** via a plurality of insulator structures **26** disposed about the perimeter of electrodes **23** and **16**. An operating potential as of about 800 volts positive with respect to the cathode is applied to the second electrode **23** via lead **27** which is tapped off the potential source **13**.

A first hollow cylindrical focus electrode structure **28** is disposed upstream from the second electrode **23**. The first electrode **28** is conveniently formed by depositing a conductive metal, as of aluminum, onto the inside wall of the envelope **2** and is joined to the face plate **3** via mating metallic frames **30** as of Kovar. The first electrode **28** has an electron entrance aperture **29** at the upstream end thereof and an electron exit aperture **31** at the downstream end thereof, such entrance and exit apertures being of approximately the same size. The electron entrance aperture **24** of the second electrode **23** is disposed within the electron exit aperture **31** of the first electrode **28** to form a two cylinder electron focusing lens. A suitable operating potential as of about 240 volts positive with respect to the cathode is applied to the first electrode **28** via lead **32** tapped off the source of potential **13**.

The conductive electrode **5** which is mounted within the domed face plate **3** includes a cylindrical extension portion **5'** to facilitate proper focusing of the electron images emitted from the photocathode **7**. The cylindrical extension **5'** is coaxially spaced within the mouth **29** of the first cylindrical focus electrode structure **28** to form a two cylinder electron focus lens.

It has been found that when the various electrode structures within the tube **1** have the following relative dimensions normalized to the maximum diameter of the first focusing electrode, d, that optimum resolution is obtained over substantially the entire surface of the image converter screen **8**. More particularly, a resolution of 70 line pairs per inch at the input or 28 line pairs per millimeter on the output screen **8** is readily obtained. The optimum normalized dimensions are: anode electrode apertures **21** of $0.12d$ diameter and an anode length of $0.19d$, third electrode **16** having an entrance aperture of $0.45d$ in diameter at the mouth which is constricted to $0.27d$ in diameter midway along the length with the length of the mouth portion being $0.13d$ and the constricted midportion being $0.22d$ in length, the second electrode **23** having a central aperture $0.60d$ in diameter and $0.29d$ in length, and the first electrode **28** having a central aperture $1.0d$ in diameter and $0.53d$ in length with the axial spacing from the center of the face plate **3** to the end of the cylindrical skirt **5'** being $0.24d$. For the above relative dimensions, optimum resolution was obtained when the potentials applied to the various electrodes were as follows, where A is the potential applied between the photocathode **7** and the image converter screen **8**: anode potential $= A$, third electrode **16** potential $= 0.1A$, second electrode **23** potential $= 0.03A$, and first electrode **28** potential $= 0.01A$.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a minifying image tube, means forming a curved photoemitter electrode for receiving a photon image and converting same into an electron image, means forming a flat fluorescent image converter screen of relatively small dimensions relative to said photoemitter for bombardment by the electron image emitted from said photoemitter and for converting the electron image into an optical image of reduced size compared to the size of the electron image as emitted from said photoemitter, means forming an electron accelerating and focusing electrode structure disposed between said photoemitter and said converter screen for accelerating the electron image to relatively high velocity and for focusing same onto said flat image converter screen, said electron focusing and accelerating electrode structure including a plurality of coaxially aligned axially spaced centrally apertured electrodes insulatively supported relative to each other to permit independent operating potentials to be applied thereto in use, successive ones of said electrodes taken in the direction from said photoemitter toward said converter screen having successively smaller central apertures through which the electron image is accelerated and focused, each of said central apertures having a mouth portion facing the photoemitter and an exit portion facing said converter screen, the improvement wherein, each of said focusing accelerating electrodes is cylindrical with the mouth portions of each successively smaller electrode being disposed within the exit portion of the next preceding larger electrode to define a series of convergent electron focusing lenses, and said electrode having the smallest central aperture constitutes an anode and is disposed adjacent said converter screen with the mouth portion of its central aperture being disposed within the exist portion of the next preceding one of said centrally apertured focusing and accelerating electrodes, whereby both electrodes have a geometry so that the equipotentials at the mouth of said anode are shaped to obtain near uniform resolution of the electron image focused upon said flat converter screen over essentially all parts of said converter screen.

2. The apparatus of claim 1 wherein the central aperture of said electrode immediately preceding said anode has an exit portion with dimensions constricted substantially relative to the dimensions of its mouth portion.

3. The apparatus of claim 2 wherein said central apertures in said electrodes have approximately the following relative dimensions where *d* is the maximum diameter of the first upstream focusing electrode, anode electrode apertures 0.12*d* in diameter and 0.19*d* in length, next preceding upstream electrode from said anode having an aperture 0.45*d* in diameter at the mouth constricted to 0.27*d* in diameter midway along its length with the length of the mouth portion being 0.13*d* and the constricted mid portion being 0.22*d* in length, the second upstream electrode from said anode having a central aperture 0.60*d* in diameter and 0.29*d* in length, and the first upstream one of said electrodes having a central aperture 1.0*d* in diameter and 0.53*d* in length.

4. The apparatus of claim 3 including means for producing and applying the following potentials to said electrodes where A is the potential applied between said photoemitter and said converter screen: A potential to said anode electrode, 0.1*A* potential to said next preceding electrode from said anode, 0.03*A* to said second electrode upstream from mid anode and 0.01A to said first electrode.

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