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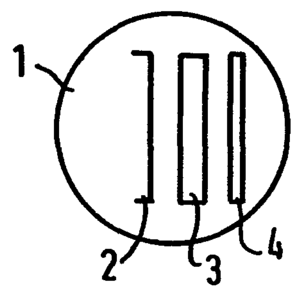
(54) X-ray detector tube.

(57) An X-ray detecor tube comprising an elongate housing (l) having an elongate cathode (2) and an elongate anode (4) mounted therein to extend essentially parallel with each other. During operation, an electrical potential is applied across the anode and the cathode of the evacuated tube. A channel plate (3) is mounted inside the housing between the cathode and the anode to extend essentially parallel therewith.



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X-ray detector tube.

The invention relates to an X-ray detector tube comprising an elongate housing having an elongate cathode and an elongate anode mounted therein to extend essentially parallel with each other, in which an electrical potential is applied across the anode and the cathode during operation and the tube has been evacuated.

Such a detector tube is disclosed in Dutch patent application 79,00878.

A drawback inherent in the prior detector tube is that the intensification of the electrons released in the cathode in response to incident X-radiation for emission to the anode is relatively poor. As a result, for example, no photodiodes can be used at the anode for detecting the image produced on the anode as in such diodes the noise and the dark current constitute too large a part of the final signal current. Other types of electronic processing of the signal received at the anode are likewise problematic on account of the extremely poor signal strength.

It is therefore an object of the invention to provide an X-ray detector tube in which the intensification of the X-ray image detected by the cathode is considerably greater than that in the prior tube.

To this end, in accordance with the invention the detector tube is provided with a so-called channel plate mounted between the cathode and the anode to extend essentially parallel therewith.

The use of such a plate in proximity focus tubes is known per se. The operation of such a channel plate, which is made of semiconductive glass and includes a very large number of small channels extending normal or practically normal to the surface of the plate, is described in, for example, the article "Een beeldversterker met pijpenplaat voor harde röntgenstraling" by V. Chalmeton in Philips Technisch Tijdschrift, 37, No. 5/6, 1977, pages 128-134.

A major advantage of the use of a channel plate in an X-ray detector tube of the type described in Dutch patent application 79,00878 is that, for achieving a good result, the channel-shaped apertures in the plate may be of larger diameter than those in the known channel plate, while also the channel-shaped apertures may be spaced a larger distance apart from each other. This permits a cheaper manufacture of the channel plate. When using a channel plate in a detector tube of the present type, the resultant intensification may be as much as 1000 times greater than that in the prior tube. Furthermore, such use results in improved image quality as the spacing between the cathode and the surface of the channel plate facing this cathode is less than the spacing between the anode and the cathode in the prior tube, which spacing is extremely critical in connection with the inevitable inequalities on the cathode surface.

In a detector tube with channel plate according to the invention a conventional anode can be used, i.e. a phosphor layer deposited on an anode support, which anode is operative as a viewing screen. The image formed on this viewing screen can be further processed by means of, for example, photodiodes as well as conventional optical means.

The anode is preferably arranged for permitting electronic processing of the electrons incident thereon, which electrons are representative of the intensified X-ray image.

A number of embodiments of anodes for use in an X-ray detector tube with channel plate will be described in greater detail hereinafter with reference to the accompanying drawings, in which:

Fig. 1 shows a detector tube according to the invention with a channel plate and a conventional phosphor layer anode;

Fig. 2 shows a detector tube according to the invention with a channel plate and a first type of anode adapted for electronic processing of the anode signal;

Fig. 2a shows a variant of an anode that can be used in the tube of Fig. 2;

Fig. 2b shows another variant of the anode that can be used in the tube of Fig. 2;

Fig. 3 shows a side view of another type of X-ray detector tube with a channel plate, in which an anode of Fig. 2a is mounted;

Fig. 4 shows a side view of yet another type of X-ray detector tube with a channel plate, in which an anode of Fig. 2b is mounted;

Fig. 5 shows a side view of an X-ray detector tube of Fig. 3 including another type of anode;

Fig. 6 shows a front view of a variant of the anode that can be used in the embodiment of Fig. 5;

Fig. 6a shows a cross-sectional view along line VIa-VIa in Fig. 6; and

Fig. 7 shows a side view of yet another type of anode.

In the figures, identical components have been designated by identical reference numerals.

Fig. 1 shows in cross-sectional view an X-ray detector tube comprising an elongate housing 1 and a cathode support 2 on which a layer of X-ray detection material, such as CsI, and a photocathode are provided in known per se manner, which layer and photocathode are not shown. A channel plate 3 extends substantially parallel with cathode support 2. This plate is made of a semiconductive glass and includes a large number of small channels extending essentially normal to the surface of the plate. For example, the channels may have an aperture of 100 micrometer and may be spaced a distance of likewise 100 micrometer apart from each other. The plate has a thickness of, for example, 40 times the diameter of the channels. An anode support 4 extends essentially parallel with channel plate 3 at some distance therefrom.

In a detector tube shown in Fig. 1 the electrical potential differences may be, for example: 100-1000 volts between cathode 2 and the surface of channel plate 3 facing cathode 2; 500-1500 volts between the surfaces of channel plate 3 facing anode 4 and cathode 2, respectively; and 5-10 kvolts between anode 4 and the surface of channel plate 3 facing anode 4.

The tube shown in Fig. 1, the envelope of which is made of glass, preferably has its inner surface provided with a conductive coating of, for example, copper evaporated thereon. Otherwise, free electrons in the detector tube may strike the glass tube wall and cause this wall to become locally charged. Such a charge can so disturb the field in the tube that the image of the cathode as formed on the anode, which image is normally undistorted in principle, becomes slightly distorted indeed. Moreover, such a charge can cause flashover within the tube and the resultantly occurring light effects disturb the image and reduce the contrast. The conductive coating on the inner surface of the tube captures the free electrons and takes care of their removal.

In order to minimize the occurrence of undesired reflections of the blue light generated in the CsI layer on the cathode, the conductive coating is preferably of copper, which is a poor reflector to blue light.

In the embodiment of Fig. 1 a known per se phosphor layer (not shown) is provided on anode support 4. The phosphor elements in this layer are caused to fluoresce by the electrons emitted by the photocathode in response to incident X-radiation and intensified by channel plate 3, so that an X-ray image is produced which can be further processed by conventional techniques, for example by using optical means, or by scanning by means of photodiodes.

In the embodiment shown in Fig. 2 the anode support 4 is made of an insulating material, such as glass or ceramic material, on which a large number of mutually insulated, parallel, strip-like conductors 5 has been deposited by, for example, evaporation in the manner shown in Fig. 2a and Fig. 2b. Each strip conductor 5 is operative as an independent anode on which the electrons multiplied in number by the channel plate are collected. The charge on the respective strip conductors 5 is removed by means of a large number of leads extending through the tube wall via associated vacuum-tight bushings 6, which leads are connected to strip conductors 5 at the bottom end of anode support 4 in the embodiment of Fig. 2a and at alternately the bottom end and the top end of anode support 4 in the embodiment of Fig. 2b.

It is also possible to have the portion(s) of insulating anode support 4 carrying the ends of strip conductors 5 protrude from the detector tube, so that no additional leads and bushings are required and the ends of strip conductors 5 protruding from the tube can be connected directly to electronic circuitry operative to further process the signals received at the strip conductors.

Fig. 3 shows a variant of the detector tube of Fig. 2, which includes an anode support with strip conductors arranged in the manner of Fig. 2a. Housing 7 of the detector tube has a tubular shape and has its forward end covered by a foil 8 that is transmissive to X-radiation, which foil permits a vacuum to be maintained in the tube. Vacuum-tight glass-soldered joint 9 seals anode support 4 to tubular housing 7.

Fig. 4 shows a variant of the embodiment of Fig. 3, in which the detector tube includes an anode support with strip conductors arranged in the manner of Fig. 2b.

Again, the housing of the detector tube has a tubular shape and consists of a first housing section 7' and a second housing section 7" with anode support 4 mounted between these housing sections. Glass-soldered joints 9 ensure a vacuum-tight seal between the housing and the anode support. In the embodiment of Fig. 3 strip conductors 5 protrude beyond the bottom end of the tube and in the embodiment of Fig. 4 strip conductors 5 alternately protrude beyond the top end and the bottom end of the tube, so that each of strip conductors 5 is contactable outside the housing. It will be clear that the embodiment of the anode support according to Fig. 2b may also be applied to the detector tubes shown in Fig. 3 and the anode support according to Fig. 2a to the embodiment of the detector tube shown in Fig. 4.

Strip conductors 5 on the anode support are maintained at a, for example, 100 volts higher voltage than the voltage at the exit end of the channel plate. The charge on anode strips 5 can be sequentially applied to an amplifier through an electronic switch mounted on an electronic print located outside the detector tube, and can then be further processed. To prevent charging of insulating support 4 between strip conductors 5, the insulating support should either be made of a material of very low electrical conductivity or be provided with a layer of low electrical conductivity on its face supporting the strip conductors.

The strip conductors may have a length of, for example, 10 mm and may be spaced a distance of, for example, 0.5 mm apart on the anode support. The strip conductors collect all charge originating from a strip of, for example, CsI of the same height as that of the conductors, which strip is provided on the cathode support.

In the embodiment shown in Fig. 5 the anode consists of an insulating support 4 of, for example, glass or ceramic material, through which support 4 conductive pins 10 extend. Pins 10 allow removal of the charge to outside the detector tube. In this embodiment, support 4 is at the same time operative as a vacuum seal for the tubular housing 7. Pins 10 may form a one-dimensional as well as a two-dimensional pattern, the latter being shown in Fig. 5. Inside housing 7 the pins are connected to electrically conductive strips in the case of a one-dimensional pattern or to electrically conductive islands, such as 10' in Fig. 5, in the case of a two-dimensional pattern.

Such strips or islands are operative as collectors for the flow of electrons multiplied by channel plate 3. On the outside of the tube the pins are connected to one or more amplifiers through electrical switches. This connection can be established, for example, via a plate 11 provided with contact points 12 arranged in a pattern corresponding to that of pins 10. Also in the embodiment of Fig. 5 the charge striking the anode support at regions between the strips or islands 10' is to be removed.

Fig. 6 shows a variant of an anode by means of which a two-dimensional image can be formed. To this end, strip conductors 13 have been evaporated on anode support 4 in the manner of Fig. 2a. However, each strip conductor 13 consists of a number of conductors deposited in superposition but separated by intermediate insulating layers 16, with each conductor being shorter than the ones thereunder to define islands 13' receiving the electrons from a corresponding region of the cathode. The charge received on islands 13' can be removed at the bottom end of strip conductors 13 via contact spots 13".

In further elucidation of the embodiment of

Fig. 6, Fig. 6a shows a cross-sectional view along lines VIa-VIa in Fig. 6, in which the thickness of the evaporated strips has been highly exaggerated for the sake of clarity.

In the embodiment shown in Fig. 7 the anode comprises a phosphor layer 14 deposited on an insulating anode support 4 which, similar to the embodiment of Fig. 2, is provided with mutually parallel strip conductors 5. These strip conductors, however, are transmissive to the light generated in the phosphor. A layer 15 of aluminium foil is provided on the phosphor screen, which layer 15 should be electrically insulated relative to the strip conductors. Electrons penetrating through the aluminium foil into the phosphor layer loose their kinetic energy as they produce excited centers, which emit light after recombination. Electrons having sufficient energy to pass through the phosphor layer reach the underlying conductive strips 5 and can be processed in the manner described above with reference to Fig. 2. A small potential difference between aluminium foil 15 and conductive strips 5 is desired but not always necessary.

An X-ray detector tube with channel plate and with an anode as shown in Fig. 7 can produce both an optical two-dimensional image and, concurrently therewith, an electrical one-dimensional image.

CLAIMS

1. An X-ray detector tube comprising an elongate housing having an elongate cathode and an elongate anode mounted therein to extend essentially parallel with each other, in which an electrical potential is applied across the anode and the cathode during operation and the tube has been evacuated, characterized in that a channel plate is mounted inside the housing between the cathode and the anode to extend essentially parallel therewith.

2. A detector tube according to claim 1, characterized in that the housing has a tubular shape and has its forward end covered by a metal foil that is transmissive to X-radiation, the anode support being mounted in vacuum-tight fashion against the rear end of the housing.

3. A detector tube according to claim 1, characterized in that the housing has a tubular shape and has its forward end covered by a metal foil that is transmissive to X-radiation, the support being mounted in vacuum-tight fashion between the forward end and the rear end of the tubular housing.

4. A detector tube according to claim 1, 2 or 3, characterized in that the anode comprises a support with a phosphor layer deposited thereon.

5. A detector tube according to claim 1, 2 or 3, characterized in that the anode comprises a support of insulating material on which a large number of electrical strip-like conductors are provided, which conductors extend

essentially normal to the longitudinal axis of the housing and each have a first end and a second end.

6. A detector tube according to claim 5, characterized in that the strip-like conductors are located within the housing and are each connected to a lead extending through the tube wall via a vacuum-tight bushing.

7. A detector tube according to claim 5, characterized in that the first ends of all strip-like conductors are located adjacent one edge of the anode support and that the second ends are located at a distance from the opposite edge of the anode support.

8. A detector tube according to claim 5, characterized in that the first ends of the strip-like conductors are alternately located adjacent one edge of the anode support and at a distance therefrom, and that the second ends are alternately located at a distance from the opposite edge of the anode support and adjacent said other edge.

9. A detector tube according to claim 5, characterized in that the electrical strip-like conductors consist of a number of electrically conductive layers deposited by evaporation in stepwise superposition, insulating layers being interposed between the electrically conductive layers.

10. A detector tube according to claim 7, 8 or 9, characterized in that the strip-like conductors protrude from the tubular housing.

11. A detector tube according to claim 2 or 3, characterized in that the anode support includes a large number

of electrically conductive pins extending through the anode support to protrude from the housing, which pins are connected inside the housing to electrically conductive elements.

12. A detector tube according to claim 11, characterized in that the electrically conductive elements are point-shaped.

13. A detector tube according to claim 11, characterized in that the electrically conductive elements are strip-shaped.

14. A detector tube according to claim 1, 2 or 3, characterized in that the anode comprises an anode support having provided thereon a number of electrically conductive, transparent, strip-like elements extending parallel with each other and essentially normal to the longitudinal axis of the housing, and that said elements are provided with a phosphor layer having its surface facing the channel plate provided with a layer of aluminium foil.

15. A detector tube according to claim 5 or 11, characterized in that the anode support is made of a material of poor electrical conductivity.

16. A detector tube according to claim 5 or 11, characterized in that the anode support has its surface facing the channel plate provided with a layer of material of poor electrical conductivity.

17. A detector tube according to claim 1, 2 or 3, characterized in that the inner wall of the housing is coated with a copper layer.

FIG.1

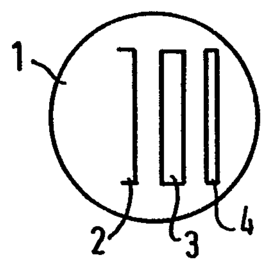


FIG.2

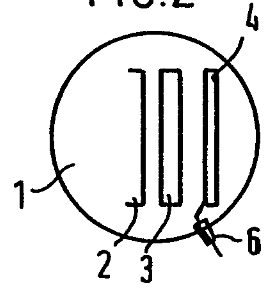


FIG.2a

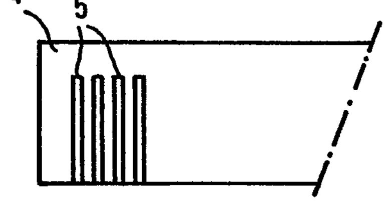


FIG.2b

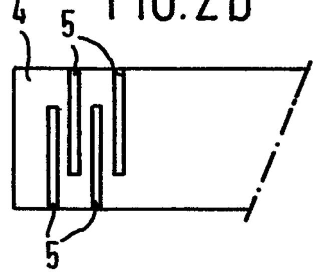


FIG.3

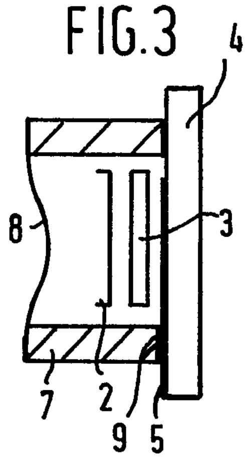


FIG.4

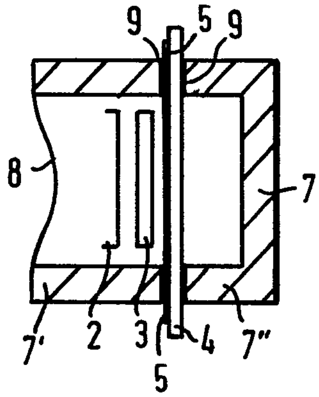
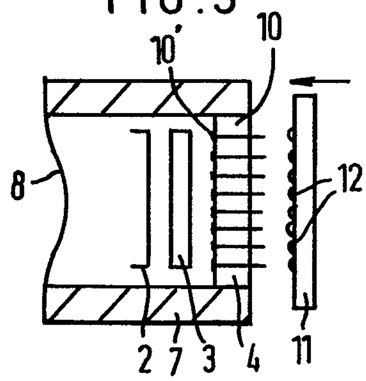


FIG.5



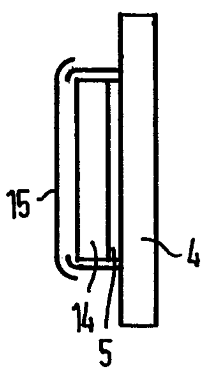


FIG.7

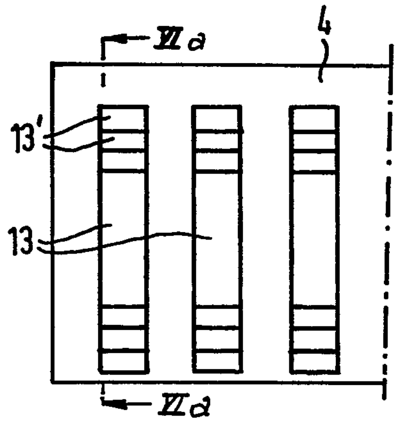


FIG.6

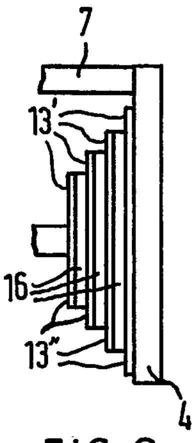


FIG.6a

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EUROPEAN SEARCH REPORT

Application number

EP 85 20 1095

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	PATENTS ABSTRACTS OF JAPAN, vol. 7, no. 88 (E-170)[1233], 12th April 1983; & JP - A - 58 14 457 (NIPPON DENKI K.K.) 27-01-1983 * Abstract * ---	1-4	H 01 J 31/50 H 01 J 31/49
Y,D	US-A-4 341 955 (MULDER et al.) * Abstract; figures 1-4 * ---	1-4	
A	L.MARTON et al.: "ADVANCES IN ELECTRONICS AND ELECTRON PHYSICS, vol. 33a, J.D.McGEE et al.: Photo Electronic Image Devices, Proceedings of the Fifth Symposium held at Imperial College London, 13th-17th September 1971, 1972, Academic Press, New York, US; I.C.P.MILLAR et al.: "Channel electron multiplier plates in X-ray image intensification" * Page 154, lines 5-8; figure 8 * ---	1-4	TECHNICAL FIELDS SEARCHED (Int. Cl.4) H 01 J 31 H 01 J 29
A	US-A-2 896 088 (J.LEMPERT) * Column 2, line 57 - column 3, line 26; figure * ---	1-4	
A	SCIENTIFIC AMERICAN, vol. 245, no. 5, November 1981, pages 46-55, New York, US; M.LAMPTON: "The microchannel image intensifier" * Page 55 * --- -/-	5-13	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10-10-1985	WITH F.B.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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EUROPEAN SEARCH REPORT

Application number

EP 85 20 1095

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-A-1 764 095 (N.K.ACKER) * Page 4, lines 1-5; figure 1 * ---	11,12	
A	FR-A-1 411 133 (TEKTRONIX) * Page 1, left-hand column, lines 1-8 * ---	14	
A	US-A-4 186 302 (WANG) -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

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X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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