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CRT X-RAY GENERATOR WITH BEAM VELOCITY MODULATION FOR EQUALIZING RADIATION

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Fig. 1

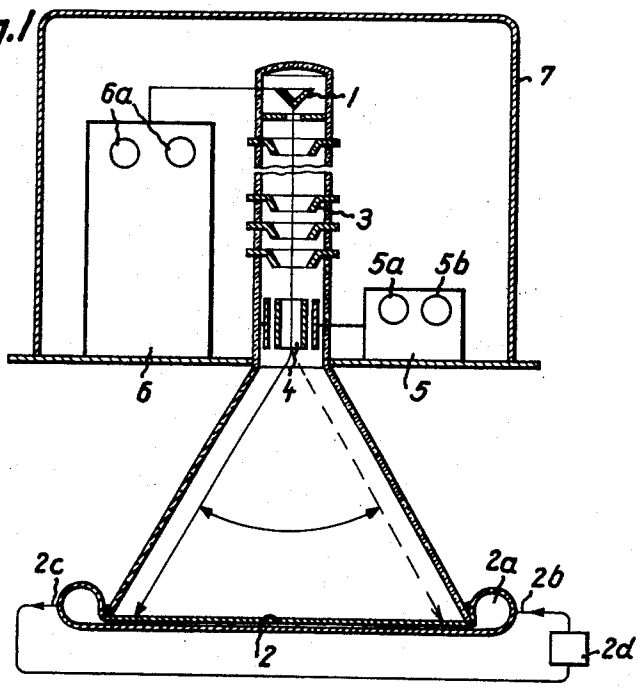


Fig. 2

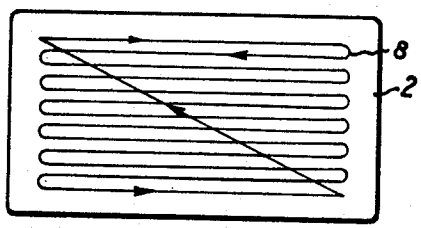


Fig. 3

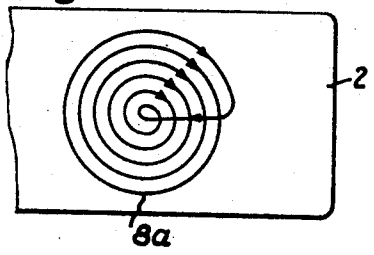
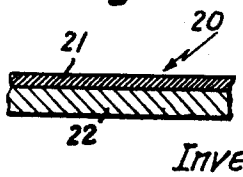


Fig. 4



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CRT X-RAY GENERATOR WITH BEAM VELOCITY MODULATION FOR EQUALIZING RADIATION

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14 Claims. (Cl. 250—99)

The present invention relates to a high power X-ray tube having a large anode penetrated by rays.

At the present time, high power radiation sources are used more and more in both research and industry. These sources are either highly active radioisotopes, or apparatus of various sorts, the latter having the advantages that they can be turned on and off at will. Examples of apparatus for producing high energy electrons are Van de Graaff or belt-type accelerators, resonant transformer sets, cascade accelerators, and linear accelerators, all of which presently operate in the mev. region (1 mev.=10^6 ev. or electron volts) and produce electron beam powers of 100 kilowatts maximum. In such accelerators, the electrons are made to travel along an acceleration path, after which they pass through a thin metallic window out of the vacuum chamber. The electrons will lose but little energy as they pass through the window, so that the power loss due to the window is small. Consequently, the window will not have to be cooled very much.

In some accelerators the electron beam, as the same passes through the vacuum chamber, is periodically moved back and forth, for example, by a suitable electromagnetic deflection system operating at a frequency of about 50 to 200 cycles per second. The beam will thus trace a straight line along the window. In this way, the beam width can be continually adapted to whatever material is being subjected to the radiation.

The main drawback of electron accelerators is that the depth which the electrons will penetrate, in the material being subjected to the radiation, is relatively small. For example, the penetration depth in water is 5 mm. per mev. This disadvantage is overcome by high power X-ray tubes. The state of the art today is such that X-ray tubes can operate with relatively low voltages but very high currents, namely, currents of the order of 0.5 to 2 amperes. The anode of an X-ray tube will have a large surface area having a load capacity of the order of several hundred watts per square centimeter. However, due to the fact that the transformation from electrical to Roentgen or X-ray energy is a low efficiency process, the tubes suffer very substantial anode losses, which reach as high as 100 kilowatts. This, of course, makes it necessary to provide special anode configurations and cooling means.

In order to obtain high dosages, it is generally sought to make the specific surface load (i.e., power per unit area of the anode) as high as possible, and in order to obtain as homogeneous a radiation field as possible, it is sought to make the focal area of the anode as large as possible. The drawback of existing tubes, which operate with acceleration voltages lying between 100 and 200 kilovolts, is the low efficiency with which the electrical energy is transformed into Roentgen energy. The efficiency can be improved if the tube is operated at higher voltages, such as one megavolt or higher. The difficulty here, however, is that it has up to now not been possible to build a tube capable of operating at such high voltages by using components suitable for tubes operating at the lower voltages.

It is, therefore, a primary object of the present invention to provide a tube which overcomes the above-mentioned drawbacks of the prior art, and, with this object in view, the present invention resides mainly in a high power X-ray tube comprising an anode having a surface area, a cathode for producing an electron beam directed toward the surface area of the anode, accelerating means arranged between the cathode and the anode for accelerating the beam toward the latter, and deflecting means arranged between the accelerating means and the anode and capable of deflecting the beam in two dimensions for causing the beam to trace a two-dimensional path on the surface area of the anode.

In practice, an X-ray tube according to the instant invention makes use of an anode having a large surface area, which anode is penetrated by the X-rays. The beam will generally be of small cross section and the deflecting means will, in effect, spread the beam so that the latter wll trace the two-dimensional path on the surface area of the anode, with the scanning speed of the deflecting means being varied such that there is obtained ahead of the anode a local homogeneous radiation field.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a sectional view of an X-ray tube according to the present invention.

FIGURE 2 is a front view of the anode and shows the path which is traced thereon by the electron beam.

FIGURE 3 is a front view of the anode but showing another path traced thereon by the electron beam.

FIGURE 4 is a fragmentary sectional view of an anode usable in an X-ray tube according to the instant invention.

Referring now to the drawing, the same shows an X-ray tube having a cathode 1 and an anode 2. Arranged between the cathode and anode, and located in the neck of the tube, is an electron accelerating system having electrodes 3. Behind the last of the electrodes 3 there is an electrostatic deflection system 4, connected to a suitable power source 5, capable of deflecting, in two dimensions, the beam emanating from the cathode 1 and accelerated by the electrodes 3. The system 4 is so controlled, in a manner known per se, that the electron beam is caused to trace on the anode 2 the two-dimensional path 8 shown in FIGURE 2.

The cathode 1 is connected to a suitable high voltage generator 6, capable of delivering about 1 megavolt. The tube neck, as well as the power source 5 and the high voltage generator 6, are arranged within a pressure tank 7.

It will be seen from the above that the beam is spread, by the deflection system 4, onto the surface area of the anode. The deflecting means themselves, which, instead of being electrostatic as shown in FIGURE 1, can be electromagnetic, are relatively simple and thus allow the tube to be controlled in such a manner as to obtain easily manageable anode loads. The spreading of the beam is necessary because the potential distribution of the accelerating system, produced by the electrodes 3 lying at different intermediate potentials, prevents the use of thick beams which are normally used in high power X-ray tubes, such beams of large cross section normally giving large focal areas.

As described above, the beam may sweep the surface area of the anode 2 in a line-by-line manner as shown in FIGURE 2, such sweeping being known per se in the television art where, to be sure, the operation is carried out at substantially lower voltages. Alternatively, the path may be along a spiral, as shown at 8*a* in FIGURE 3. This will be achieved by appropriate controlling of the deflection system 4. In this way, the surface area swept by the

beam can be either rectangular or circular, as will best suit the needs of the situation. The X-ray tube according to the present invention may thus be considered as an inverse rotary anode X-ray tube in the sense that the anode is stationary while it is the beam which is rotated.

By appropriately controlling the deflection means, the latter being equipped with variable amplitude control means indicated schematically at 5*a*, the focal area may readily be adjusted to any desired size. Furthermore, by appropriately varying the current and/or voltage supplied to the tube, by means of the generator control indicated schematically at 6*a*, the specific load of the anode, i.e., the power per unit area, can be adjusted at will. In practice, it has been found that the specific load can readily be varied between a maximum of, for example, 1000 watts per square centimeter and a minimum of, for example, 10 watts per square centimeter.

In many instances, it is desired to obtain a local homogeneous radiation field ahead of the anode. This can be achieved by adjusting the scanning speed, to which end the source 5 is equipped with a suitable control 5*b*, by means of which the electron beam will be moved faster in the middle of the anode area than in the region of the edges thereof. This will compensate for the drop of dosage which would otherwise occur at the edges.

The accelerating system for producing a high energy electron beam in the megavolt range can be of conventional construction; for instance, the system may operate on the principle of a high frequency cascade accelerator, it being understood that other accelerating systems suitable for producing a high current electron beam in the megavolt range can be used.

The target anode 2 will have a large area, being of the type customarily used in the afore-mentioned high power X-ray tubes operating at voltages of between 100 and 200 kilovolts and electron currents of between 0.5 and 2 amperes. The anode can be a single layer electrode made of heavy metal, as is shown in FIGURE 1, because, at the high voltage at which the tube according to the present invention operates, the absorption loss will not be of particular importance. Alternatively, the anode may be a two-layer anode 20, shown in FIGURE 4, consisting of a first layer 21 made of a heavy metal for producing the X-rays and a second layer 22, thicker than the first layer, and made of a light metal, the second layer serving as a carrier for the first layer, thereby increasing the mechanical strength of the anode.

The anode may also be provided with suitable cooling means, such as a jacket 2*a* provided with an inlet 2*b* and an outlet 2*c*, both of which are connected to a coolant circulating pump 2*d*. If the specific load to which the anode is to be subjected is low, the coolant may be a gaseous medium such as air, while with higher specific loads, the fluid medium will be a liquid such as water.

The present invention is not limited to the particular anode shape shown in the drawings. Instead, by appropriately fashioning the deflection system 4, the tube may incorporate a differently shaped anode, such as a semicylindrical anode.

It will be appreciated that the present invention has made possible a high power X-ray tube in which the electrons are converted into X-ray energy with high efficiency, and which still retains the advantages of heretofore known tubes incorporating large area anodes. In particular, it has been found that, by constructing X-ray tubes in accordance with the teaching of the present invention, power outputs can be obtained which are the same as the power outputs of the largest radioactive sources now known.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. A high power X-ray tube comprising, in combination:
   (*a*) an anode having a surface area;
   (*b*) a cathode for producing an electron beam of small cross section directed toward said surface area of said anode, said surface area being substantially greater than the cross section of said electron beam;
   (*c*) distributed potential type accelerating means arranged between said cathode and said anode for accelerating the beam toward the latter;
   (*d*) deflecting means arranged between said accelerating means and said anode and capable of deflecting the beam in two dimensions for causing the beam to trace a two-dimensional path on said surface area of said anode to cover a large focal area which itself is substantially greater than the cross section of said electron beam; and
   (*e*) means for varying the scanning speed of said deflecting means to obtain a local homogeneous radiation field ahead of said anode.

2. An X-ray tube as defined in claim 1 wherein said deflecting means are electrostatic means.

3. An X-ray tube as defined in claim 1 wherein said deflecting means are electromagnetic means.

4. An X-ray tube as defined in claim 1 wherein said path is formed by sweeping said surface area of said anode in a line-by-line manner.

5. An X-ray tube as defined in claim 1 wherein said path is formed by sweeping said surface area of said anode along a spiral, thereby producing a substantially round focal area on said anode.

6. An X-ray tube as defined in claim 1, further comprising means for varying the size of the area which is covered by said path.

7. An X-ray tube as defined in claim 1, further comprising means for varying the power supplied to said cathode and the deflection rate of said deflecting means, whereby the specific load on the focal area on said surface area of said anode can be varied.

8. An X-ray tube as defined in claim 1, further comprising means for cooling said anode.

9. An X-ray tube as defined in claim 8, wherein said cooling means comprise a jacket adjacent said anode, and means for circulating a fluid medium through said jacket.

10. An X-ray tube as defined in claim 9, wherein said fluid medium is a gas.

11. An X-ray tube as defined in claim 9, wherein said fluid medium is a liquid.

12. An X-ray tube as defined in claim 11, wherein said liquid is water.

13. An X-ray tube as defined in claim 1, wherein said anode consists of a layer of heavy metal.

14. An X-ray tube as defined in claim 1, wherein said anode consists of a first layer made of heavy metal, and a second layer, thicker than the first layer, and made of a light metal, said second layer serving as a carrier for said first layer.

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