PATENT SPECIFICATION (11) 1 558 188

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(21) Application No. 42867/75 (22) Filed 18 Oct. 1975

(23) Complete Specification Filed 11 Oct. 1976

(44) Complete Specification Published 19 Dec. 1979

(51) INT. CL.[2] H01J 35/26

(52) Index at Acceptance
H1D 2A 2R

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(19)

(54) X-RAY TUBE

(71) We, EMI LIMITED, a British company of Blyth Road, Hayes, Middlesex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to sources of X-radiation and is especially related to such sources for use with scanning radiographic apparatus.

Conventional X-ray tubes includes a source of a beam of electrons and an anode structure on which the electron beam is caused to be incident and which emits X-rays as a result of well known processes in response to the incident electrons. The anode may be a fixed structure although provision is usually made to change the anode if degradation resulting from heat generated by the electron beam becomes excessive. It is also known to provide a rotating anode which rotates about an axis to change the region of incidence thereon and thus improve the distribution of heat. The arrangement is however such that the region of incidence of the electrons, and hence the origin of the X-rays is stationary in relation to the body of the tube so that the rotation of the anode does not disturb the X-ray emission.

In certain applications, in particular developments of the radiographic technique known as computerised Axial Tomography (CAT), it is required to provide a lateral scanning motion of a beam, usually fan shaped, of X-rays relative to a body being examined. This may, of course, be achieved by a lateral motion of the X-ray tube. However X-ray tubes have been proposed, for example in British Patent Application No. 4002917 in which the incident beam is scanned across the surface of a fixed anode to provide a corresponding scan of the emitted X-rays. This arrangement necessarily requires electron scanning equipment and associated control circuits to effect the said scan.

It is an object of this invention to provide an X-ray tube providing a scanned X-ray output which does not require a scanned electron beam.

According to the invention there is provided an X-ray tube including an anode which is rotatable about an axis, a source of a beam of energy, for example an electron beam, arranged to impinge on a surface of the anode to generate X-radiation substantially at the region of incidence on said anode surface and means arranged to rotate the anode about the axis to move the region of incidence over said surface, wherein the anode is shaped so that said rotation causes the region of incidence to move in a predetermined manner relative to fixed parts of the tube so that the generated X-radiation is scanned in a predetermined manner relative to the tube.

In order that the invention may be clearly understood and readily carried into effect embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, of which:

Figure 1 shows in simplified form a cross-section of a rotating anode X-ray tube adapted in accordance with the invention and,

Figures 2 and 3 show in plan view forms of anode suitable for use with the tube of Figure 1.

To provide the scanned X-ray emission, it is proposed to adapt the known rotating anode X-ray tube. The arrangement is such that, for a fixed beam of electrons, the region of incidence of electrons on the anode is moved relative to the fixed parts of the tube in the course of the rotation, unlike the known tubes for which it remains stationary.

There is shown in Figure 1 a rotating anode tube so adapted. The tube comprises an evacuated envelope 1 which includes a

portion 2, transparent to X-rays, situated in the wall to the rear of the section shown in the drawing. An insulating part 3 of the envelope 1 supports a cathode 4 and, adjacent thereto, an electrode 5 which can be energised to act as a guard plate, control grid or focus electrode. Conventional electrical connections (not shown) are provided to the cathode 4 and electrode 5. An anode 6 is mounted on a shaft 7 journalled in bearings 8 and 9 to rotate about an axis 10 in the plane of the drawing. Rotation is produced in known manner by the cooperation of a rotor 11 mounted on shaft 7 and a stator 12 mounted adjacent to and concentric with stator 11 but outside envelope 1. Means (not shown) are also provided to apply required electrical potentials to anode 6.

In operation cathode 4 and electrode 5 co-operate to provide an electron beam 13 directed toward and preferably focussed at the anode 6 to generate X-radiation at the surface thereof. Electron beam 13 has been shown as a pencil beam but it will be understood that it may be a known form of ribbon beam having a larger dimension in one direction perpendicular to its direction of travel.

The X-ray tube and operation so far described are essentially the same as a known rotating anode tube. However, in this example the anode is appropriately shaped, for example as will be described hereinafter, so that in the course of rotation the position at which the electron beam strikes the anode is moved. Thus, as rotation takes the anode from the position shown in solid line to that shown in broken line, the point of origin moves from position 14 to position 15. The movement is in the plane of the paper along the axis of the electron beam. The radiation is emergent through the window 2 and is available for any desired purpose such as for example CAT purposes for which typically the radiation will be collimated into a fan shaped spread, in plane AA, from each successive point of origin.

Two anode shapes capable of producing the desired scanning effect are shown in more detail in plan views in Figure 2 and 3. In Figure 2 the anode 6 effectively comprises four quadrants each having a curved periphery to form a surface 16. The four periphery sections may be generally elliptical but in this example are each the same part of an equiangular spiral, two being in one sense and two in the opposite sense. In a typical embodiment the anode could be ten inches minimum diameter and fourteen inches maximum diameter for a tube operating at up to 400 kV and 1/3A. The electron beam is directed at the surface 16 in the direction shown and is incident at 17 to provide X-rays 18.

As is conventional in X-ray tubes of this class it is expected that the X-rays will be derived perpendicularly to the incident electron beam 13 although the maximum of X-ray emission will not usually be in that direction. For that reason X-rays 18 have been shown as a fan shaped spread in the perpendicular direction although collimator means for that purpose will usually be situated external to the X-ray tube envelope 1.

The anode is rotated about the axis 7 so that the point of origin of the X-rays varies from point 14 to point 15 as the point on the periphery 16 intersecting electrons 13 varies between points 19 and points 20 respectively. Thus the position of the emitted X-rays is moved parallel to the electron beam the X-rays for position 15 being indicated at 18^1. If the electrons are focussed on the anode surface it may be desirable to vary the focus of the beam as the point of contact with the anode moves. Such adjustment can be provided by conventional electromagnetic or electrostatic means, linked to the rotation of the anode, for example by use of the waveform provided to drive anode stator 12.

Figure 3 shows an alternative form of anode 6. In this example the anode surface is formed of two sections of equiangular spirals in the same sense so that the periphery 16 intersects the electron beam at points between extremes 14 and 15 during rotation of the anode. The corresponding X-ray emission which is shown at 21 for an intermediate source point 17 scans between a first limit corresponding to source point 14 and a second limit 21′ corresponding to source point 15. Since the two sections shown are spirals in the same sense they provide a steady scan of the X-rays over that range, for clockwise rotation of the anode 6, with a rapid flyback from 21′ to the first limit. The arrangement of Figure 2 provides, however, steady scans in alternate directions between the two extremes. The arrangement s otherwise generally the same for the two anode shapes.

For both anode shapes equiangular spirals have been shown to give linear scans as a function of time for a constant angular velocity of the anode. Other shapes can however be used to give other desired scanning rates or forms. For CAT purposes the anodes illustrated may require to rotate at up to 30,00 rpm to give required X-ray scan rates. However, anodes may be provided with larger numbers of facets to allow the faster scan rates without such high rotation rates. The rotation should, however, be sufficiently fast to allow proper cooling of the anode as in conventional rotating anode tubes.

It should also be noted that the arrangements shown assume that the X-rays are derived in a direction perpendicular to the incident electron beam. However, if X-rays are derived in other directions the scan

provided will also give a displacement of the point of origin along the mean direction of the derived X-rays.

As an additional feature one or more parts of the surface of the anode surface may be provided at a constant radius so that the X-ray fan can 'dwell' at one or more position of the scan for a selected time.

The anodes shown have a surface parallel to the axis of rotation. However, the surface can be inclined to that axis if desired.

Although the electron beam is shown normal to the anode axis, providing an X-ray scan in plane AA, it will be understood that this is not an absolute condition of the invention but can be varied if desired.

In an alternative embodiment the speed of X-ray scan may be changed by providing a variable rate of rotation for anode 6.

Although the invention has been described with reference to a particular tube geometry and source of electrons to generate X-rays from an anode, other geometrics and sources, for example a laser, of radiation incident on the anode, could be used in putting the invention into effect.

No specific form of cathode has been discussed since this may be of any known form. For example, the cathode described in United States Patent No. 4,126,805 may be used to provide a high power electron beam.

It should be appreciated that, in the course of the scanning motion the direction of emission of X-rays, in relation to the normal to the anode surface, may change causing a variation in the hardness of X-rays in some parts of the fan selected. This is particularly true of the anode form of Figure 2. For certain purposes, for example CAT scanning, means should be provided to correct or compensate for such variations. If desired an anode with only one spiral section may be provided.

WHAT WE CLAIM IS:-

1. An X-ray tube including an anode which is rotatable about an axis, a source of a beam of energy, for example an electron beam, arranged to impinge on a surface of the anode to generate X-radiation substantially at the region of incidence on said anode surface and means arranged to rotate the anode about the axis to move the region of incidence over said surface, wherein the anode is shaped so that said rotation causes the region of incidence to move in a predetermined manner relative to fixed parts of the tube so that the generated X-radiation is scanned in a predetermined manner relative to the tube.

2. An X-ray tube according to claim 1 in which the said anode is formed with a peripheral surface at a variable radius from said axis and is arranged so that said region of incidence is on said peripheral surface.

3. An X-ray tube according to claim 2 in which the periphery of the anode includes one or more sections of substantially equiangular spiral form in a plane perpendicular to the said axis.

4. An X-ray tube according to any of the previous claims the anode being shaped to provide a movement of said region of incidence comprising a series of steady movements in one direction with a rapid flyback in the other direction therebetween.

5. An X-ray tube according to claim 2 in which the anode is a disc with a substantially elliptical plan form perpendicular to the said axis.

6. An X-ray tube according to any preceding claim in which the periphery of the anode includes one or more sections of substantially constant radius about said axis in a plane perpendicular thereto.

7. An X-ray tube according to any preceding claim in which the said means for rotating is arranged to rotate the said anode about the said axis at a substantially constant angular velocity.

8. An X-ray tube according to any preceding claim in which the rotation is through a plurality of complete revolutions to repetitively scan the X-rays relative to the tube.

9. An X-ray generating tube comprising an evacuated envelope, an anode mounted inside the envelope for rotation about an anode axis, a source of an electron beam for propagating along a beam axis fixed with respect to the envelope and impnging on the peripheral surface of the anode at an area which moves along the peripheral surface upon rotation of the anode about said anode axis, said peripheral surface being irregularly shaped to cause said area of impingement of the electron beam to move with respect to the envelope upon rotation of the anode, said peripheral surface being made of a material generating x-radiation originating at the area of impingement and propagating away from the anode, and means for rotating the anode about the anode axis to thereby move the area of impingement relative to the envelope and scan the x-radiation relative to the envelope in a manner determined by the shape of the peripheral surface and the anode rotation.

10. An X-ray tube substantially as herein described with reference to the accompanying drawing.

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Printed for Her Majesty's Stationery Office,
by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

1558188 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheet 1

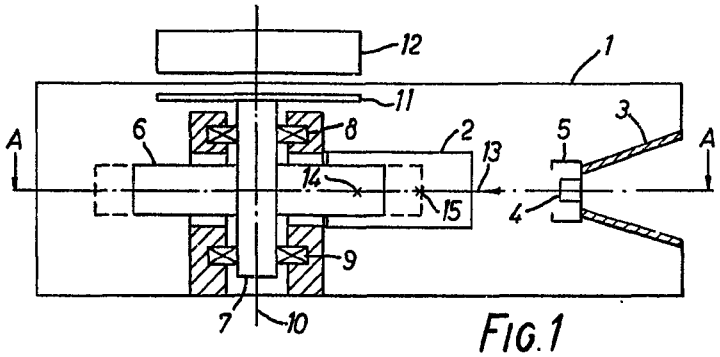

FIG. 1

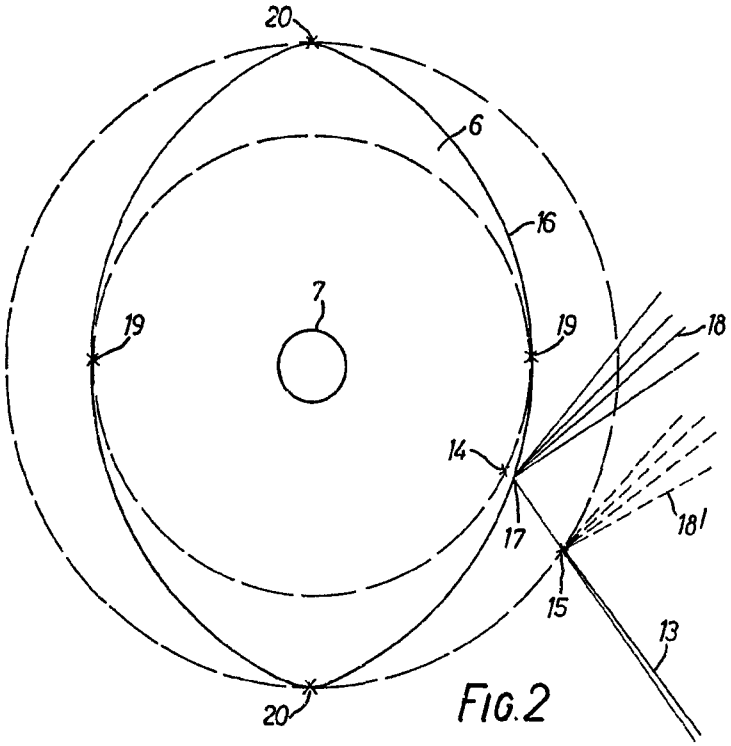

FIG. 2

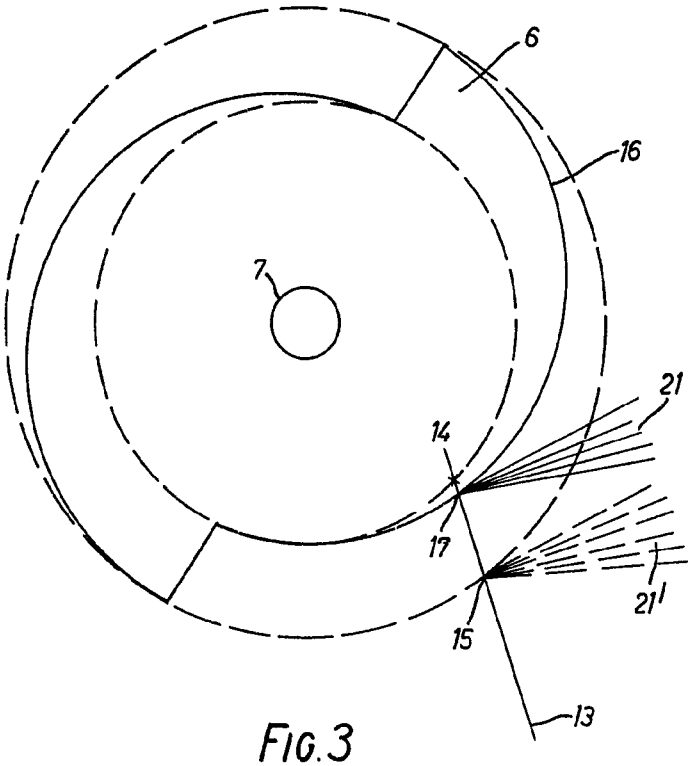

FIG. 3