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APPARATUS FOR PRODUCING CONVERGENT X-RAY BEAMS

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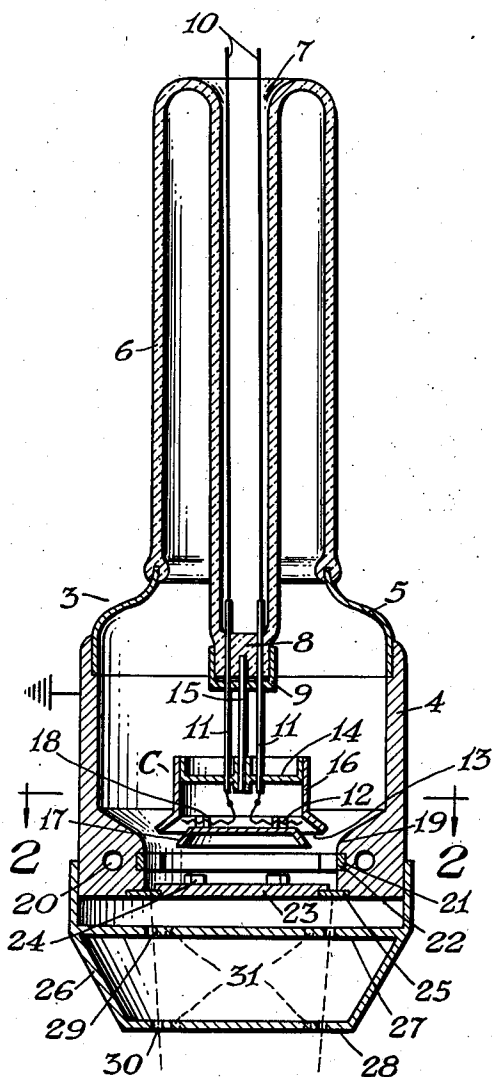


Fig. 1

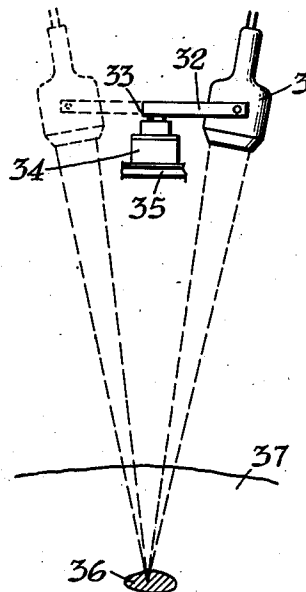


Fig. 3

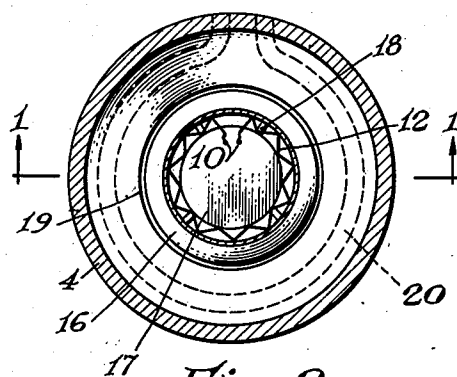


Fig. 2

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APPARATUS FOR PRODUCING A
CONVERGENT X-RAY BEAMLudo K. Frevel, Midland, Mich., assignor to The
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5 Claims. (Cl. 250-142)

1

This invention relates to a device for producing a beam of X-rays in the form of a hollow convergent cone and to apparatus including the device.

Conventional X-ray tubes produce a beam of divergent X-rays, the intensity of which decreases rapidly as the distance from the source is increased. In therapeutic uses, then, in which deep-seated tissue is to be treated with such a beam, the surface tissue, being nearer the source, is unavoidably subjected to X-rays of greater intensity. The problem of securing adequate dosage of deep tissue without serious overexposure of the surface is thus difficult. Likewise, in radiographic work, the divergence of the X-ray beam is sometimes disadvantageous in that diffuse shadow patterns are obtained.

It is accordingly the principal object of the present invention to avoid these disadvantages by providing a device for generating a beam of X-rays in the form of a hollow cone converging to a focus. Another object is to provide apparatus for using the device in treatment of deep-seated tissue.

Basically, the new device comprises an X-ray tube having an annular or ring-shaped target and a shield associated with the tube having one or more annular slits so placed with respect to the target as to restrict the issuing X-rays to the form of a convergent conical beam.

The apparatus of the invention, in a preferred embodiment, may be explained with reference to the accompanying drawing in which

Fig. 1 is a vertical section along the line 1-1 of Fig. 2, showing the assembly of an X-ray tube and shield;

Fig. 2 is a horizontal section along the line 2-2 of Fig. 1; and

Fig. 3 is an elevation showing the X-ray tube of Fig. 1 mounted for movement in a fixed path about its focal point.

The X-ray tube indicated generally as 3 is of the hot-cathode high-vacuum type and is intended for operation with grounded anode at voltages of the order of 40 to 200 kilovolts. A conventional protective case surrounds the tube but is not shown in the drawings.

The tube 3 is formed with a hollow steel envelope or anode 4 surmounted by an annular copper cap 5 soldered to the anode. This cap necks down at its top and is sealed into a conventional tubular glass insulator 6.

A central well 7 in the insulator terminates in a base 8 over which is fitted a protective metal cap 9. Lead-wires 10 surrounded in part by a

2

cable covering not shown, pass down the well 7 and are sealed in insulating sleeves 11 which in turn are sealed through the base 8 and cap 9 and extend into the envelope.

The cathode structure C is centered in the envelope 4 and contains a tungsten filament 12 welded to the lead-wires 10. The filament is disposed in the form of a loop of substantial diameter transverse to the envelope and centered axially therein. The filament is surrounded by a tungsten shield which has an annular opening 13 directed obliquely downward. The shield includes a transverse top 14 through which the sleeves 11 extend, the top being supported by an insulating rod 15 mounted in the base 8. A tubular side-portion 16 fits over and extends downwardly from the top 14 and flares outwardly at the level of the filament 12 to form one side of the opening 13. The other side of the opening is formed by a correspondingly flared rim of the bottom piece 17 which is held in place by means of legs 18 attached to the side-piece 16.

The envelope 4 is thickened inwardly at its lower portion to provide a tubular target-support 19 in which a passage 20 for cooling water is formed. A groove 21 is cut into the inside vertical wall of the target-support at a position such as to be in the electron path defined by the annular opening 13 in the cathode shield. Into this groove is placed an annular target 22 which as shown is coaxial with the filament and spaced axially therefrom and has its X-ray generating face parallel to its axis. For convenience, the target is made of a three-segment tungsten ring of rectangular cross-section which is pressed into the groove 21 to be flush with the wall of the target support 19.

The tube 3 is closed at its lower end by a copper or lead-alloy disk 23 having a diameter slightly less than that of the target-support 19; the disk being held in place by lugs 24 on the adjoining wall. The space between the target-support 19 and the disk 23 is covered by an annular X-ray-transparent window 25, conveniently a beryllium ring. This ring is inset into appropriate annular grooves cut in the disk and target-support and is soldered in place. In this construction the annular window 25 is co-axial with the target 22 and spaced axially therefrom and has an effective diameter less than that of the target.

Fitted over the lower end of the tube 3 is a tubular shield-support 26 which is integral with two lead-alloy shielding disks 27 and 28 each parallel to the plane of the target 22 and spaced

axially therefrom and from each other. Annular slits 29 and 30 of limited width are cut in the shielding disks co-axial with the target 22, spider legs 31 being left to support the central portions of the disks. The diameters of the slits are chosen so that each is less than that of the window 25 and so that each slit is in the conical surface defined by the target 22 and the window slit 25, i. e. so that the slits are in the conical X-ray beam passing from the target through the window. In a preferred construction, the angle of the cone defined by the target 22, window 25 and slits 29 and 30 may be approximately 10 degrees.

In practice, the tube 3 is constructed by conventional techniques and is exhausted and sealed off. In use, the anode 4 is grounded, a sufficient voltage is applied between the lead-wires to heat the filament 12 to incandescence, and a high-voltage is applied between the filament 12 and the anode 4. Under these conditions, electrons liberated at the filament escape the cathode structure through the opening 13 and impinge on the annular target 22, generating X-rays. These rays, although leaving the target in all directions, are for the most part absorbed in the shielding of the tube. However, those rays moving toward the annular window 25 pass through and leave the tube largely as a convergent beam. This X-ray beam is sharpened by the slits 29 and 30 in the shielding disks 27 and 28, which latter screen off radiation in all directions except that of the cone. The X-rays finally passing through the lower slit 30 are in the form of a hollow convergent cone and come to a fairly sharp focus, as shown in Fig. 3.

A typical use of the focused X-ray beam produced by the tube 3 is in deep X-ray therapy as illustrated in Fig. 3. For this purpose, the tube 3 is mounted on a horizontal supporting arm 32 secured to a vertical shaft 33 which may be rotated by a motor-and-gear-reducer 34 held by a support 35. The tube 3 is fixed to the arm 32 in a position tipped slightly in the plane of the arm 32 and shaft 33 to focus the convergent X-ray beam on a point beneath the center of the support 35. Then, when the shaft 33 is rotated, the X-ray tube 3 describes a circular path while maintaining the X-ray beam convergent on a fixed point.

In treating a region of deep-tissue 36 covered by overlying tissue 37, the tube 3 and support 35 are adjusted so that the focal point of the X-ray beam is within the region 35. The motor drive 34 is then energized to move the tube 3 in its circular path. The convergent beam of X-rays remains focused in the tissue 36, but the path of the beam through the overlying tissue is constantly changing. For this reason, and the further fact that the X-ray beam is hollow, no single portion of the overlying tissue receives more than a very minor fraction of the total X-ray dosage applied at the focal point. Overexposure of the upper tissue is thus avoided.

It will be understood that the foregoing description is illustrative rather than limitative and that variations of the apparatus shown may be made within the scope of the following claims.

What is claimed is:

1. In a device for producing a beam of X-rays

in the form of a hollow convergent cone, an X-ray tube having a cathode and an annular target, a shield spaced from the target parallel to the plane thereof and having therein an annular slit co-axial with the target and having a diameter less than that of the target, and a second shield parallel to the first at a point more remote from the target and having therein an annular slit co-axial with the target and having a diameter less than that of the first slit such as to be in the direct conical beam passing from the target through the first slit.

2. In a device for producing a beam of X-rays in the form of a hollow convergent cone comprising: an X-ray tube having a cathode, an annular target, and an annular X-ray window of diameter less than that of the target co-axial therewith and spaced axially therefrom; and a shield spaced axially from the window parallel to the plane of the target and having therein an annular slit co-axial with the target, the diameter of the slit being less than that of the window and such that the slit is in the direct conical X-ray beam passing from the target through the window.

3. In a device for producing a beam of X-rays in the form of a hollow convergent cone: an X-ray tube having a cathode, an annular target co-axial with and spaced axially from the cathode and having its annular X-ray generating surface substantially parallel to the axis of the target, and an annular X-ray window of diameter less than that of the target co-axial therewith and spaced axially therefrom; and at least two shields spaced axially from the window and from each other, each parallel to the plane of the target and each having therein an annular slit co-axial with the target, the diameter of each slit being less than that of the window and such that the slit is in the direct conical X-ray beam passing from the target through the window.

4. A tube for producing a hollow conical beam of X-rays comprising a cathode, an annular target, and an X-ray opaque partition spaced axially from the target in the direction remote from the cathode and closing the tube, such partition having therein an annular X-ray transparent window co-axial with the target and of diameter less than the latter.

5. A tube according to claim 4 wherein the target is spaced axially from the cathode and has a cylindrical X-ray generating face parallel to the axis.

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