

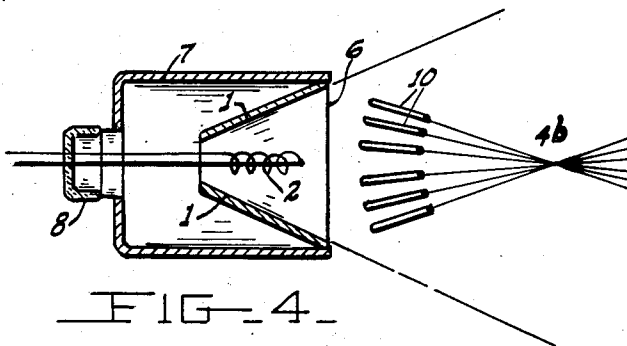
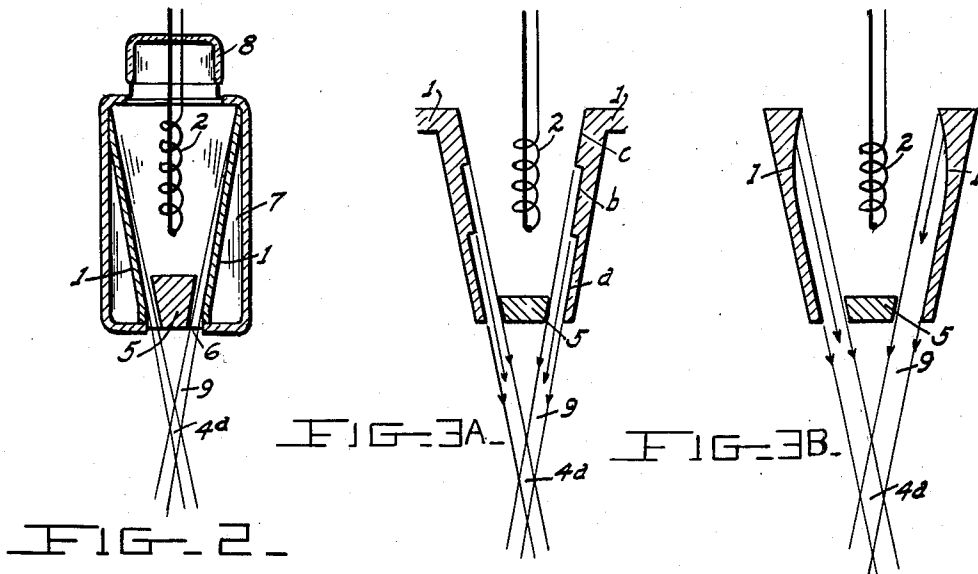
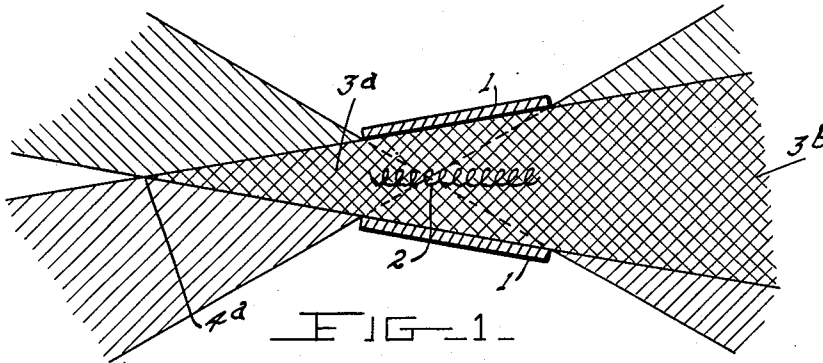
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DEVICE FOR PRODUCING X-RAYS

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DEVICE FOR PRODUCING X-RAYS

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1

This invention relates to a device for the production of X-rays having preferred directional characteristics and to apparatus including the device.

Conventional X-ray tubes comprise a source of electrons and means of focusing these electrons to a small point on a target which is the X-ray source. X-rays radiate in all directions from the focal spot on the target. Disadvantages of such tubes include the difficulty of focusing the electrons to as fine a spot as possible, the problem of dissipating the heat generated at the focal spot, and the fact that, due to the divergent nature of the radiation from this focal spot, the X-ray intensity diminishes rapidly as the distance from the target is increased.

It is the object of this invention to avoid these difficulties by providing a device which generates X-rays without the necessity for focusing the electron beam; which makes use of an exceptionally large target area, thus minimizing heating; and which by virtue of geometrical considerations in its design allows preferential selection of the radiation from the target so that the resulting X-ray beam is divergent, parallel, or convergent to a point, as desired. Another object is to provide apparatus for using the device in suitable therapeutic applications.

Basically, the device comprises an X-ray tube having a conical shaped target colinear with an axially arranged electron source, and associated shields or collimators to aid in selecting the desired portion of the radiation. A feature of the device is that the target performs part of the collimating function. Another feature is that as the axial length of the conical target is increased, the X-ray output may be increased proportionally with the increase in area.

In describing this invention, reference is had to the accompanying drawings in which like characters designate corresponding parts in all the views.

Figure 1 is a diagrammatic view of the target having a conical bore or passage, and the filament or source of electrons in the passage.

Figure 2 is a diagrammatic view showing the device in longitudinal section.

Figures 3a and 3b are longitudinal sectional views of slightly modified forms of the target.

Figure 4 is a view, similar to Figure 2, of a modified form of the device.

Figure 1 is a section showing a target 1 with a conical bore coaxial electron source or filament 2. The target is at a positive potential with respect to the filament. The filament, 55

2

when heated, emits electrons which are drawn radially to all portions of the wall of the bore of the target. The shaded areas show the sectioned distribution pattern of X-radiation which is generated at the target surface. The doubly shaded areas 3a, 3b, indicate regions of very high radiation density since these regions receive contributions from all target areas. It should be noted that the boundaries of both the converging and diverging regions are set by the shielding or collimating action of the target itself. Also should be noted the region beyond the cross-over point or cone apex 4a which is devoid of any radiation as a result of the self collimation of the target cone. Also, note that each point in the doubly shaded regions receives contributions from all target areas so the apex, or cross-over point, receives its contributions from rays which travel at grazing incidence to the surface of the cone.

It will be seen from Figure 1, that the shape of the distribution pattern of the doubly shaded areas and in particular the position of the apex, or cross-over point, is independent of the axial length of the conical target. Furthermore, since all portions of the conical bore contribute to these regions, the actual radiation density may be varied within wide limits without excess heating of the target by merely varying the axial length of the cone.

Figure 2 shows, in section, one embodiment of the device. The conical target 1 enclosed in the vacuum chamber 7 is arranged to be concentric with the electron emitting filament 2, whose lead wires enter the vacuum chamber through the insulator 8. In this embodiment, a collimating plug or shield 5 is so placed that the only radiation ensuing from the tube is that making small angles with the target wall. With this combination, the X-ray beam consists of a hollow conical sheath 9 which converges to the cross-over point 4a, after which it expands as a similar hollow cone. Note that the intensity at the cross-over has been unchanged by the addition of the collimating plug. It still receives contributions from the entire target. The effect of the collimating plug is to remove the inner portions defining the inner surface of the converging cone and the outer surface of the diverging cone. This plug may be used interior to, or exterior to, the vacuum chamber. Without it, the X-ray intensity is substantially constant along the axis within the region 3a of Figure 1, but drops to zero at points on the axis past 4a. The self collimation of the target defines the

outer surface of the converging cone and the inner surface of the diverging cone.

The size of the cross-over region is determined by the width of the annular collimating passage formed by the collimating plug 5 and the target 1. Note that the radiation density at the cross-over is much greater than at any other region in the sheath, either before or after cross-over, since all the radiation in the sheath passes through this region. Therapeutically, this embodiment is capable of delivering a much greater useful radiation dose than other existing X-ray tubes.

As is seen from Figures 1 and 2, the cross-over is determined by the self collimating properties of the target, this limitation being accomplished by absorption of the X-radiation in the target. The smaller the angle made with the target wall by the grazing rays, the greater the chance that they will be absorbed by irregularities on the target surface. This effect increases with axial length of the target and makes itself evident as a reduction in the intensity at the cross-over.

Figures 3a and 3b show means for minimizing this effect for any given width of collimating groove and length of target cone.

In Figure 3a, the target cone is shown made up of a series of cones arranged to give a step-like effect, the total rise of the steps being limited to the maximum allowable width of the radiation sheath as determined by the collimating plug and the target. The effect of this is to minimize the self absorption of X-radiation by the target. Thus, radiation from step b is not absorbed by step a. In general, the greater number of steps, the less self-absorption. If the number of steps becomes very great, the effect approaches that of a smooth curve, as shown in Figure 3b. This condition is achieved only at the loss of some of the self collimating properties hitherto described.

Although the practical embodiment shown in Figure 2 makes use of the radiation issuing from the convergent end of the conical target, useful directional effects can also be obtained with a tube provided with a window to allow the radiation to emerge from the divergent end of the target.

Referring to Figure 1, every point in the doubly cross hatched region 3b diverging from the conical target and indeed self collimated by the target contains radiation contributions from all portions of the target 1.

Figure 4 shows an embodiment utilizing portions of this radiation in such a way as to obtain a beam of X-rays in the form of a substantially solid cone convergent to a point of cross-over and diverging again after this cross-over. It will be seen that the X-ray tube structure is identical with that of Figure 2 except that the collimating plug has been omitted, and the conical target 1 has been reversed to present its larger or open end to the tube window 6. Thin walled metal tubing 10 may be arranged in a bundle exterior but not limited to the exterior of the tube as shown. If the tubes are parallel in the bundle, the radiation is collimated to be parallel. Likewise, they can be arranged to produce a collimated divergent beam or a collimated convergent beam, as is shown in Figure 4. Such collimators may be used with the radiation from either the converging or diverging end of the conical target for a range of convergence or divergence angles determined by the self collimating properties of the target itself.

Either the embodiment of Figure 1, or of Fig-

ure 4, has important therapeutic value. For example, in the treatment of deep seated tumor, the position of the patient is adjusted so that the cross-over point 4a or 4b falls upon the tumor.

In such instance, the radiation density at the tumor is greater than that in the tissue either before or after it. Thus, by the geometry of its X-ray beam, this tube offers an improvement over the conventional type X-ray tube using parallel or diverging radiation since in those tubes the radiation density constantly diminishes along the beam.

What I claim is:

1. In an X-ray generating device, an X-ray tube having a cathode filament and circuits therefor, said device being characterized by a target having an internal truncated conical bore, the filament being located within the bore and extending lengthwise of the axis of the bore, and means at the smaller end of the conical bore to confine the X-rays generated by the target in a hollow conical path having a focal area located in the axis of the conical bore beyond the smaller end of the bore of the target.

2. In an X-ray generating device, an X-ray tube having a cathode filament and circuits therefor, said device being characterized by a target having an internal truncated conical bore, the filament being located within the bore and extending lengthwise of the axis of the bore, and means at the smaller end of the conical bore to confine the X-rays generated by the target in a hollow conical path having a focal area located in the axis of the conical bore beyond the smaller end of the bore of the target, said means comprising a shield located within the smaller end of the conical bore and having its periphery spaced from the opposing walls of the bore providing an annular outlet passage for the X-rays generated in the target.

3. In an X-ray generating device, an X-ray tube having a cathode filament and circuits therefor, said device being characterized by a target having an internal truncated conical bore, the filament being located within the bore and extending lengthwise of the axis of the bore, and means at the smaller end of the conical bore to confine the X-rays generated by the target in a hollow conical path having a focal area located in the axis of the conical bore beyond the smaller end of the bore of the target, said means comprising a shield located within the smaller end of the conical bore and having its periphery spaced from the opposing walls of the bore providing an annular outlet passage for the X-rays generated in the target, the conical bore being provided with a series of successive annular steps on the wall of the bore of the target with the risers of the steps facing toward the annular outlet.

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