

Dec. 23, 1958

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FINE FOCUS X-RAY TUBES

2,866,113

Filed Oct. 6, 1953

2 Sheets-Sheet 2

FIG. 2

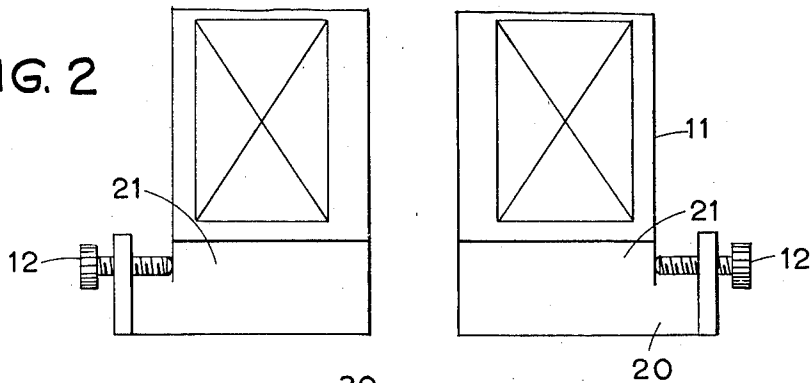
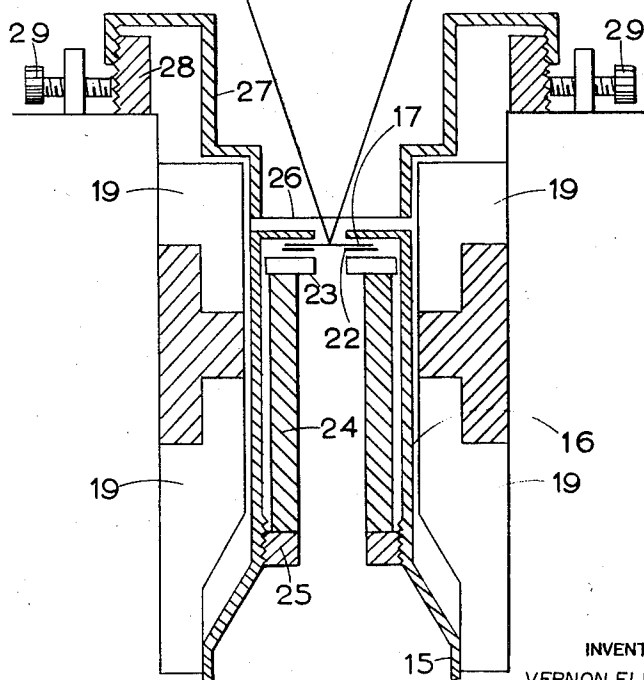


FIG. 3.



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2,866,113

FINE FOCUS X-RAY TUBES

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Application October 6, 1953, Serial No. 384,496

Claims priority, application Great Britain October 7, 1952

9 Claims. (Cl. 313—57)

This invention relates to X-ray tubes and in particular to X-ray tubes producing a fine focal spot suitable for use in X-ray shadow microscopy. The fine focal spot may approximate to a point source of X-rays or it may constitute a line source of minute width and controlled length.

Hitherto X-ray sources of the order of 40 microns in diameter have been achieved, but the invention has for its object to enable much smaller sources of the order of 1 micron or less to be obtained. The lengthy investigations which have resulted in the present invention have established that special adjustability of the means for focussing the electron beam on the target and a special target construction are essential to enable the desired result to be produced.

According to the invention the target surface which constitutes part of the wall of the evacuated envelope of the tube and also serves as a window for the passage of the X-rays generated by the electron beam incident on the target, is carried by a tubular neck which passes through the field space of a magnetic electron lens which is external to the evacuated envelope, and provision is made for relative adjustment between X-ray tube and electron lens in such manner that the magnetic axis is parallel with the axis of the electron beam within the tubular neck, is coincident therewith at the target surface, and the target surface coincides with the area of least cross-section produced in the electron beam by the magnetic lens.

Reference will now be had to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of an X-ray tube according to the invention.

Figure 2 is a diagram of an alternative detail.

Figure 3 is an enlarged view of the target end of the X-ray tube of Figure 1, showing also the association of the tube with auxiliary equipment for use in X-ray shadow microscopy.

Referring first to Figure 1, the electron gun is a triode structure consisting of a filament 1, a shield 2 and an anode 3. For convenience in handling the tube, the anode 3 and the body of the apparatus are at earth potential, the accelerating voltage is obtained by applying a negative voltage to the filament 1, and the shield 2 is further biased negatively with respect to filament 1. The electron gun structure is connected to the remainder of the X-ray tube by means of a bellows 4 to facilitate the alignment of the electron beam.

In the construction shown the electron beam passes through a first electron lens 5 constituting a condenser lens. This is a magnetic lens without pole pieces. Its presence is necessary if a particularly small focal spot is required at the target surface, although for some purposes it can be dispensed with. Beyond the electron lens 5 the tube body 6 is provided with a connection 7 to the pumps for evacuating the tube. The construction shown is of a demountable character which introduces

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the necessity for pumping. The invention can however equally be applied to a permanently sealed-off tube.

At the end of the tube remote from the electron gun is a platform 8 which supports the X-ray target and also the magnetic electron lens for concentrating or focussing the electron beam on the target. Standing on the platform 8 externally of the tube is a tripod support 9 to which is affixed a table 10 on which the objective lens 11 is adjustable. In the drawing the adjustment from left to right is effected by means of screws 12 associated with the table 10. Adjustment in the plane of the table 10 at right angles to the direction of the screws 12 is effected by a similar set of adjusting screws (not shown). By means of the tripod with its adjustable legs, the table 10 can be tilted in relation to the axis of the electron beam from the electron gun and if desired the axial distance from the gun can also be adjusted. The axial alignment of the magnetic axis of the lens 11 with the axis of the electron beam is performed by means of the adjusting screws 12 associated with the table 10.

The actual target of the X-ray tube is constituted by a lamina 17 which also forms the window by means of which the X-ray beam emerges from the tube, which is known as a transmission target. This window 17 is carried at the end of a vacuum liner 15 which is attached to the tube body 6 by means of a bellows 13. The base 14 of the liner 15 extends laterally beyond the bellows 13 and is threaded for engagement with an adjusting ring 18 which enables the axial position of the liner in relation to the magnetic lens 11 to be adjusted. The body of the liner 15 terminates in a neck 16 which passes between the pole pieces 19 of the lens 11 and carries the window 17 at its end.

When the necessary axial alignment of the magnetic lens 11 with the electron beam has been effected by means of the adjustment of the tripod 9 and the adjusting screws 12, the point of minimum cross section of the electron beam resulting from the effect of the lens 11 can be brought into coincidence with the window 17 by means of the adjusting ring 18. Alternatively instead of adjusting the position of the window 17 in relation to the lens 11 the lens 11 could be movable in the axial direction for this purpose or alternatively the pole pieces 19 could be adjustable axially in relation to the lens 11.

When employing both a condenser lens 5 and an objective lens 11 as shown in Figure 1 it is necessary to have the complete freedom of adjustment of the lens 11 so as to obtain as small a source of X-rays as possible. If however the lens 5 is dispensed with, a simpler adjustment is possible by substituting for the independent adjustment by tripod and by centering screws 12, an arrangement as shown in Figure 2 in which the lens 11 is supported on a fixed spherical surface 20 which is concentric with the filament 1. Interposed between the lens 11 and the table 20 is a mount 21 which is secured to the lens 11 and has a curvature complementary to the spherical surface 20. By means of two sets of adjusting screws 12 (only one set being shown) the lens 11 is adjusted in position on the table 20, the lateral displacement being associated with a corresponding tilting movement due to the spherical curvature, with the result that the radial relationship between the axis of the lens 11 and the filament 1 is maintained.

Further details of the construction of the target end of the X-ray tube of Figure 1 are shown in Figure 3. This construction is particularly applicable to demountable tubes. The metal foil 17 constituting the window of the tube is clamped in position against the end face of the neck 16 by means of a clamping ring 23 but with the interposition of an apertured soft metal washer 22 which not only serves to form a vacuum seal but also ensures good metallic contact. Indium or lead is suitable for the

washer 22. The clamping ring 23 is urged against the soft metal washer 22 by means of a thrust sleeve 24 which is inserted within the neck 16 and is urged into position by means of a screw-ring 25 in engagement with a screw thread at the lower end of the neck 16. Owing to the small dimensions of the apparatus, the overall diameter of the sleeve 16 being 6 mm. and the opening in the end face of the neck and in the washer 23 being $\frac{1}{4}$ mm. in an actual tube constructed in accordance with Figures 1 and 3, it is necessary to provide means remote from the end of the neck 16 for clamping the window 17.

The window 17 is a metal foil consisting of the metal which is appropriate for the X-rays it is desired to generate. From practical considerations foils of tungsten, gold, copper, silver, molybdenum are suitable. The thickness of the foil should be of the same order of magnitude as the size of X-ray spot to be formed, i. e. approximately 1 micron for shadow-microscopy purposes. The size of the central aperture in the clamping ring 23 is determined by the need to provide a stop to limit the spherical aberration of the lens. The opening in the end surface of the neck 16 against which the window 17 is clamped should be as small as possible in order to minimize the load on the foil due to the pressure difference on the two sides. In practice it is convenient to have this aperture the same size as that in the clamping ring 23.

In the interests of clarity the clamping ring 23, the soft metal washer 22, the window 17 and the end of the neck 16 have been shown in spaced relationship in Figure 3. In practice they are of course clamped tightly together to form a very compact and solid end giving good mechanical strength and heat transfer properties.

Figure 3 also shows the association of an X-ray tube according to the invention with auxiliary equipment for use in X-ray shadow microscopy. The X-ray tube is capable of giving an intense and exceedingly small focal spot of the order of 1 micron or less in diameter, and thus provides what can be regarded as a point source of X-rays. The specimen to be examined is mounted on a support 26 outside the tube but in the proximity of the target-window 17. The specimen support 26 is carried by a tube 27 which is adjustable on a ring 28 so that the distance from window to specimen can be adjusted. Centering screws 29 (only one pair being shown) enable the ring 28 to be moved in a plane parallel to the window 17 for the purpose of centering the specimen with respect to the X-ray beam. The X-ray shadowgraph is recorded on a photographic plate 30. The magnification of the shadowgraph is determined by the geometry of the system and no limitations are imposed by the grain of the photographic plate. The construction of the tube permits the specimen to be brought very close to the target-window, thus giving high geometrical magnification. Stereography can be carried out very simply in this apparatus. All the specimen is in focus at once with the same resolution, as given by the spot size, although different planes are magnified by different amounts. Three-dimensional imaging can thus be obtained by taking two photographs from slightly different viewpoints; as divergent illumination is employed, the specimen may either be tilted or translated between exposures. The resulting stereographic pairs may be mounted to show directly the spatial configuration of the specimen in a way which is not possible in optical microscopy, owing to the limited depth of focus at high resolution.

I claim:

1. An X-ray tube comprising an elongated, evacuated envelope, means for producing an electron beam along a given axis disposed at one end of said envelope, a magnetic condenser lens surrounding the axis of the beam and disposed adjacent said beam producing means, a metal foil serving as a transmission target disposed at the other end of the envelope and positioned to intercept the beam, said foil constituting a portion of the wall of said envelope, a metal tubular neck portion also forming a

portion of the wall of said envelope and supporting said metal foil in position, a magnetic objective electron lens external to said envelope and surrounding said tubular neck portion in the immediate vicinity of said target, said objective lens being secured to said neck portion, means for adjusting said objective lens and neck portion relative to the remainder of said envelope to parallel the magnetic axis of the lens and said given axis of the beam within the neck portion and to align said axes at the target surface, and means to adjust the target in an axial direction relative to the objective lens such that the target surface coincides with the area of least cross-section of the electron beam produced by the lens, whereby an X-ray source of the order of one micron or less may be obtained.

2. An X-ray tube as set forth in claim 1 wherein the last-named means comprises means for axially displacing the neck portion relative to the objective lens.

3. An X-ray tube as set forth in claim 1 wherein a pair of metallic members are provided at the end of the neck portion and secured thereto, the target metal foil is clamped between said metallic members in good heat transfer relationship therewith, and one of said metallic members has a central aperture limiting the aberration of the objective lens.

4. An X-ray shadow microscope comprising an X-ray tube as claimed in claim 1 in combination with means for mounting a specimen external to said tube but in the vicinity of said target, and means for recording the X-ray shadowgraph of the specimen.

5. The method of producing an X-ray source of the order of one micron or less in an X-ray tube having a tubular neck portion supporting a target foil and surrounded by a magnetic lens, which comprises the steps of producing and projecting an electron beam through the neck portion at the target, adjusting the magnetic lens and target relative to the electron beam to parallel the magnetic axis of the lens and the axis of the beam within the neck portion and to align said axes at the surface of the target, and adjusting the magnetic lens and target relative to one another until the target surface coincides with the area of least cross-section of the electron beam.

6. The method of producing an X-ray source of the order of one micron or less in an X-ray tube having a tubular neck portion supporting a target foil and surrounded by a magnetic lens, which comprises the steps of producing and projecting an electron beam through the neck portion at the target, displacing and pivoting the magnetic lens and target relative to the electron beam to parallel the magnetic axis of the lens and the axis of the beam within the neck portion and to align said axes at the surface of the target, and axially displacing the magnetic lens and target relative to one another until the target surface coincides with the area of least cross-section of the electron beam.

7. An X-ray tube comprising an envelope, means for producing and projecting an electron beam along a given axis in said envelope, a target member mounted in a position to be impacted by said electron beam, electron lens means in the vicinity of said target for focusing said beam thereon, and means for adjusting the relative positions of the electron lens and target and target and beam-producing means in a plurality of directions so that the lens magnetic axis coincides with the beam axis both in the envelope and at the surface of the target, and the target surface is located substantially at the focus of the beam, thereby to produce at said target an X-ray source of the order of one micron or less in diameter.

8. An X-ray tube comprising an envelope including a tubular neck portion, means for producing and projecting an electron beam along a given axis in said envelope, a transmission target member mounted on said neck portion and in a position to be impacted by said electron beam, electron lens means surrounding said neck portion in the vicinity of said target for focusing said beam

thereon, and means for adjusting the lens and target relative to each other and to the beam-producing means in sufficient directions at which the lens magnetic axis coincides with the beam axis both in the envelope and at the surface of the target, and the target surface is located substantially at the focus of the beam, thereby to produce at said target an X-ray source of the order of one micron or less in diameter.

9. An X-ray tube comprising an evacuated envelope including a tubular neck portion, means for producing and projecting an electron beam along a given axis in said envelope, a transmission target member mounted at an end of said neck portion and in a position to be impacted by said electron beam and constituting part of the envelope, electron lens means external to the envelope and surrounding the neck portion in the immediate vicinity of said target for focusing said beam thereon, means for adjusting the relative positions of the electron lens and target and relative to the beam-producing means in at least three right-angle directions at which the lens

magnetic axis coincides with the beam axis both in the envelope and at the surface of the target, and the target surface is located substantially at the focus of the beam, thereby to produce at said target an X-ray source of the order of one micron or less in diameter, and means for supporting a specimen in close proximity to said target but outside the envelope for irradiation by X-rays from said source.

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