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2,849,634

LINEAR ELECTRON ACCELERATORS

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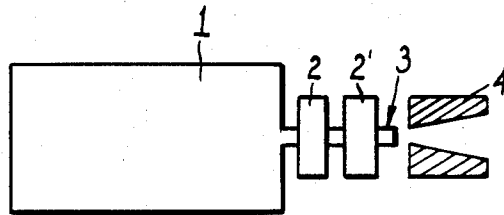


Fig. 1

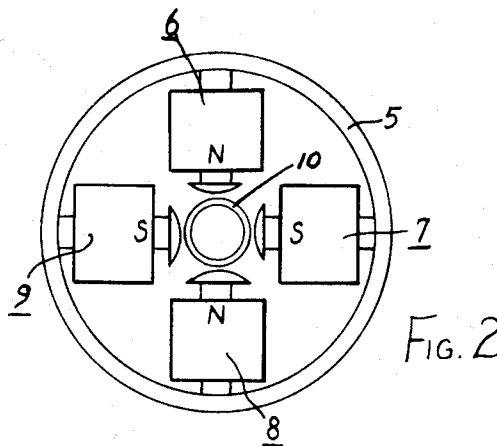


FIG. 2

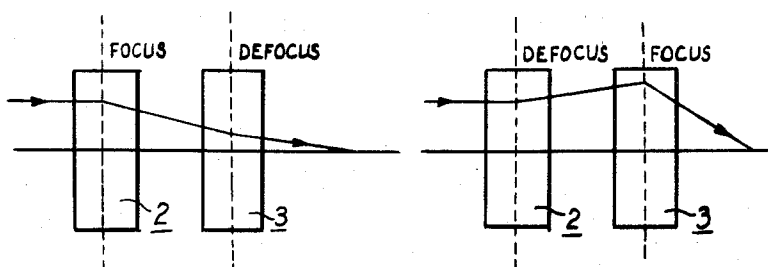


Fig. 3a

Fig. 3b.

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LINEAR ELECTRON ACCELERATORS

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4 Claims. (Cl. 313-57)

This invention relates to linear electron accelerators and more particularly to focusing arrangements for the electrons.

The beam of electrons from a linear electron accelerator can be very suitable for the production of X-rays for industrial radiography excepting for cross-sectional size of the beam. In general, the beam from a linear accelerator is of circular cross-section, and is usually of the order 0.5 to 1 cm. diameter. The edges of the beam are not sharply defined, and conventionally the diameter of the beam is given as that diameter hole through which half the beam current will pass. If such a beam impinges on a target, and the X-rays resulting are used for radiography, the relatively large size of source results in unsharpness in the radiographs, unless the object is placed at a considerable distance from the target, which necessitates longer exposures than would otherwise be required. If the spot size were to be reduced, the object could be brought nearer, with a consequent shortening of exposure time. However, there is no point in producing a spot size of less than about 1 mm. diameter, because of inherent unsharpness due to scatter in the film, etc.

One way of obtaining a small spot size is to collimate the electron beam at the gun. However collimating the beam to a small diameter by this method results in considerable reduction in output with consequent increase in exposure times.

The purpose of this invention is to provide a means of focusing the electron beam from a linear accelerator to a small diameter with relatively little loss of beam current.

According to the present invention X-ray generating equipment comprises a linear electron accelerator in combination with a magnetic focusing assembly for focusing the beam on the target which focusing assembly comprises two or more quadrupolar magnetic lenses, successive lenses being of opposite polarity and the lenses being of different axial lengths and/or magnetic field strengths to satisfy the requirements that the beam should be brought to approximately the same focal point in the two principal planes which focal points are coincident with the target.

According to a preferred arrangement there are two quadrupolar magnetic lenses and the first lens is of shorter axial length and/or magnetic field strength than the second.

The preferred shape of the pole pieces of the magnetic lens is that of a segment of a right hyperbolic cylinder, although in practice a sufficiently close approximation can be found in the shape of a segment of a right circular cylinder. For such a lens, the transverse magnetic field strength across the principal planes is directly proportional to distance from the axis.

It has been found that with such an arrangement it is possible to reduce the cross section of the beam or the target without appreciable loss of power and without introducing noticeable astigmatism.

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The quadrupolar magnetic lenses preferably employ permanent magnets though electro magnets could be used.

Theoretically, for the preferred arrangement, there will be no astigmatism if

$$\frac{[\cos X - Z \sin X] \cosh Y - \frac{A_1}{A_2} \sin X \sinh Y}{A_2 [\cos X - Z \sin X] \sinh Y - A_1 \sin X \cosh Y} = \frac{[\cosh X + Z \sinh X] \cos Y + \frac{A_1}{A_2} \sinh X \sin Y}{[\cosh X + Z \sinh X] \sin Y - A_1 \sinh X \cos Y}$$

where

- 15 l_1 is the length of the first magnet
- l_2 is the length of the second magnet
- d is the distance apart of the magnets
- a_1 is the transverse field strength of the first magnet, unit distance from the axis
- 20 a_2 is the transverse field strength of the second magnet, unit distance from the axis
- v is the velocity of the electron

$$A_1 = \sqrt{5.3 \times 10^{10} a_1 \left(1 - \frac{v^2}{c^2}\right)^{1/2}}$$

$$A_2 = \sqrt{5.3 \times 10^{10} a_2 \left(1 - \frac{v^2}{c^2}\right)^{1/2}}$$

$$X = \frac{A_1 l_1}{v} \quad Y = \frac{A_2 l_2}{v} \quad Z = \frac{A_1 d}{v}$$

Similar expressions can be obtained for the conditions for astigmatism when more than two magnets are used, but the case of two magnets is the one of greatest interest.

The expression above can be satisfied if a_1 is less than a_2 , or l_1 is less than l_2 , or both.

A lens assembly of two magnet assemblies has been made, in which $l_1 = l_2$, but a_1 is less than a_2 by an amount to satisfy the above equation. It has been shown that such a lens has sufficiently small astigmatism to enable a beam of electrons from a 4 m. e. v. linear accelerator, initially of 1 cm. diameter, to be focused to a spot of approximately 2 mm. diameter.

In order that the invention may be more clearly understood reference will now be made to the accompanying drawing in which:

Fig. 1 is a diagrammatic view of a linear accelerator incorporating a focusing arrangement;

Fig. 2 is a cross-sectional view showing a magnet arrangement in detail; and

Figs. 3a and 3b illustrate the effect of focusing.

In Fig. 1 the reference 1 indicates the linear accelerator generally, 2 and 2' are quadrupolar magnet assemblies, 3 is the target and 4 is a collimator.

Fig. 2 shows a magnet assembly in which 5 is a yoke and four magnets 6, 7, 8 and 9 are arranged about the electron beam tube 10.

The polarities may be as indicated but would be reversed in the case of the second magnet assembly. Fig. 3a shows the path of an electron initially parallel with the axis through first a focusing and then a defocusing section. In the focusing section the electron is deflected towards the axis and its mean distance from the axis in the defocusing section is less than in the focusing section so that the net defocusing force is less than the net focusing force and there is a resultant focusing action. In the case of 3b the sections are reversed and the initial defocusing section causes the electron to be deflected from the axis so that it passes through the focusing section at a greater mean distance from the axis than in passing through the defocusing section and this again results in a net focusing action.

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What I claim is:

1. X-ray generating equipment comprising a linear electron accelerator in combination with a magnetic focusing assembly for focusing the beam on the target which focusing assembly comprises two or more quadripolar magnetic lenses, successive lenses being of opposite polarity and the lenses having relative axial lengths so chosen as to ensure that the beam is brought to approximately the same focal point in the two principal planes which focal points are coincident with the target. 10

2. X-ray generating equipment as claimed in claim 1 in which there are two quadripolar magnetic lenses and the first lens is of shorter axial length than the second.

3. X-ray generating equipment comprising a linear electron accelerator in combination with a magnetic focusing assembly for focusing the beam on the target which 15

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focusing assembly comprises two or more quadripolar magnetic lenses, successive lenses being of opposite polarity and the lenses having relative magnetic field strengths so chosen as to ensure that the beam is brought to approximately the same focal point in the two principal planes which focal points are coincident with the target.

4. X-ray generating equipment of claim 3 and including two quadripolar magnetic lenses, one of which is of greater magnetic field strength than the other.

References Cited in the file of this patent

UNITED STATES PATENTS

2,200,039	Nicoll	May 7, 1940
2,372,443	Marton	Mar. 27, 1945
2,586,559	Page	Feb. 19, 1952