

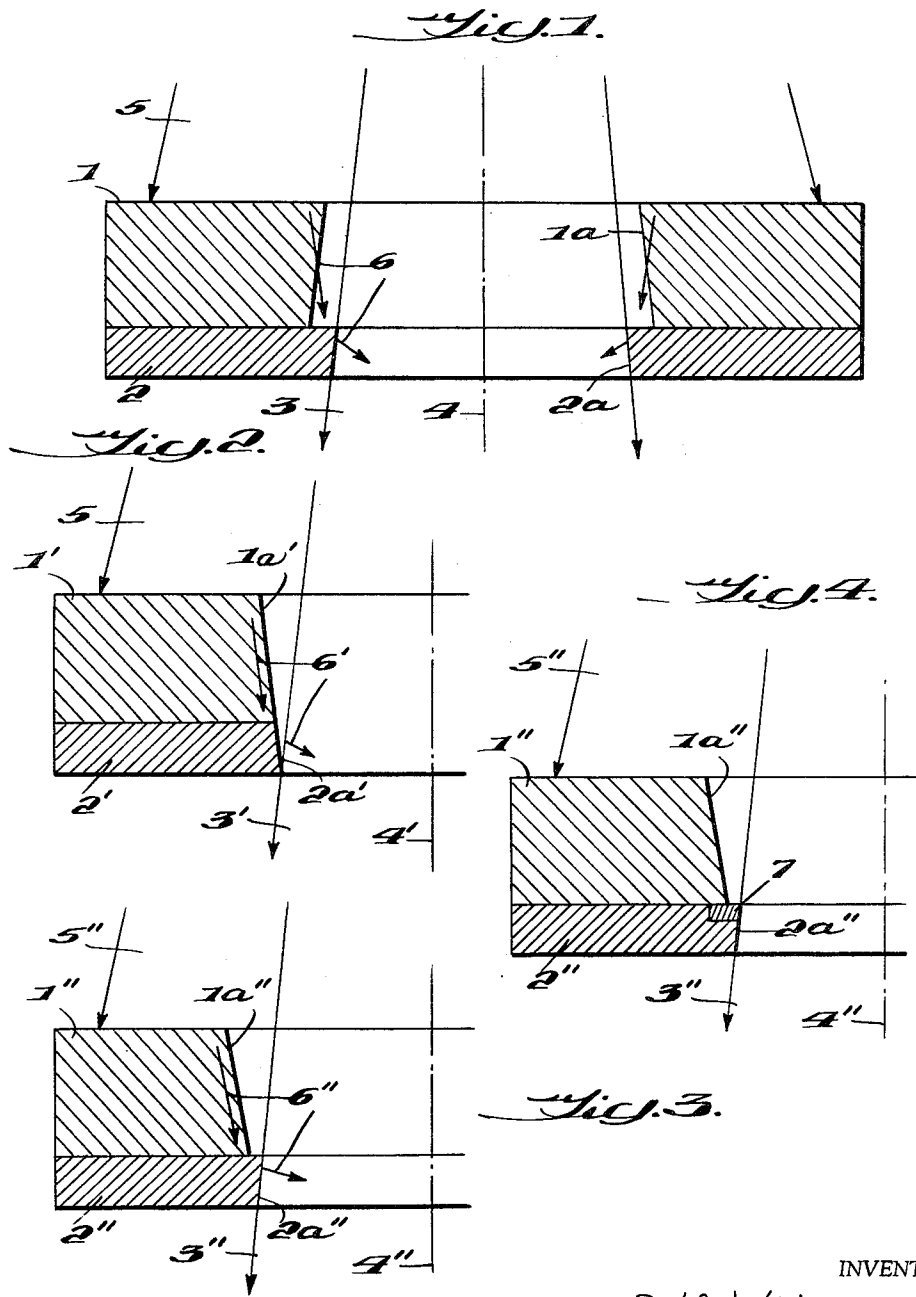
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R. WIDERÖE

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COLLIMATOR FOR BEAMS OF HIGH-VELOCITY ELECTRONS

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INVENTOR

Rolf Wideröe

BY *Pierce, Scheffler & Parker*
ATTORNEYS

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3,227,880 COLLIMATOR FOR BEAMS OF HIGH-VELOCITY ELECTRONS

Rolf Wideröe, Nussbaumen, Aargau, Switzerland, assignor
to Aktiengesellschaft Brown, Boveri & Cie, Baden,
Switzerland, a joint-stock company

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The present invention relates to beam collimators and more particularly to an improved collimator for electron beams having a high velocity.

A collimator for high velocity electron beams must perform the function of masking down a part of the field of radiation centered about the beam axis and is attended by two principal difficulties. If the material chosen for retarding the undesired electrons is a substance having a high atomic number, for example, lead, impingement of the electrons produces hard X-rays. On the other hand, if the collimator is made from a substance having a low atomic number, multiple diffusion of the electrons in the collimator causes low-energy electrons to emerge from the inner surfaces of the collimator aperture, and by mixing with high-energy electrons in the intensified beam, considerably impairs the effectiveness of the electrons which are rich in energy. This is more particularly the case because, if the undesired electrons are to be retarded by a substance having a low atomic number and low specific weight, the collimator must be made quite thick, with the result that the inner surfaces of its aperture are fairly large.

It has previously been proposed to make collimators for high velocity electrons from two substances having high and low atomic numbers, respectively, so that the electrons are retarded to such an extent in a first layer of a substance of low atomic number, that when they impinge upon a subsequent layer of a substance of high atomic number, they no longer have sufficient energy to liberate X-rays of appreciable intensity. The electrons are completely retarded in this second layer. However, if the high-velocity electrons, for example, of 35 m.e.v., encountering the collimator are to be sufficiently retarded, the first layer, i.e. the layer of low atomic number, must be so thick that there is no way of preventing stray electrons from emerging laterally into the collimator aperture and mixing with the electron beam.

The object of the present invention is to provide an improved collimator construction for high-velocity electron beams wherein troublesome stray electrons are, to a large extent, prevented from emerging. The improved collimator construction is principally characterized by the fact that the inner surfaces of its aperture are arranged further from the axis of the beam on the side at which the beam enters the collimator than on the side at which the beam emerges from the collimator.

Several different embodiments of collimators in accordance with the invention will be described and are illustrated in the accompanying drawings. In these drawings:

FIG. 1 is a view in diametral section in a plane parallel with and containing the beam axis of one embodiment of the improved collimator wherein the inner surfaces of the aperture are stepped in the direction of passage of the electron beam;

FIG. 2 is a half diametral section similar to FIG. 1 of a modified embodiment wherein the inner surface of the collimator aperture is inclined in the direction of passage of the beam;

FIG. 3 is also a half diametral section of still another embodiment which combines the characteristics of both FIGS. 1 and 2, i.e. the inner surface of the collimator aperture is both stepped and inclined relative to the beam direction; and

FIG. 4 is also a half diametral section of a further embodiment similar to FIG. 3.

With reference now to the drawings, and to FIG. 1 in particular, the electron beam collimator is constituted by an annular composite body comprised of two annular discs or layers 1 and 2 secured face-to-face, the apertured surfaces 1a, 2a of which are arranged concentrically with respect to the axis 4 of electron beam 3, which passes through the center of the apertures, the direction of the beam 3 being indicated by the arrows.

The annular disc 1 is made from a metal having a low atomic number such as, for example, aluminum and it is disposed at the side of the collimator structure where the electron beam 3 enters. The other disc 2 of the composite collimator body is made from a metal having a high atomic number and high specific weight such as, for example, lead or tungsten and is disposed at the collimator structure where the electron beam emerges. It will be noted from FIG. 1 that the central aperture 1a of disc 1 is somewhat larger in diameter than the central aperture 2a in disc 2 so as to develop a stepped characteristic. Moreover, the inner surfaces 1a, 2a of the two discs have a frusto-conical configuration divergent in the direction of the passage of the beam through the collimator. The masked-down electron beam 3 passes through the two discs, and the undesired part 5 of the beam radiation which impinges on the first layer or disc 1 of the collimator is partially retarded therein and is completely retarded in the second layer or disc 2.

Due to the difference in aperture diameters by which the inner surface 1a of disc 1 is set back relative to the inner surface 2a of disc 2, the inner surface 1a is located further from the beam axis 4 than is the inner surface 2a. The directions of the emerging stray electrons are indicated by the arrow 6. It will be apparent from FIG. 1 that the stray electrons emerging from the disc 1 are substantially trapped by the inwardly projecting disc 2, or emerge from this disc at such a large angle to the beam axis 4 that they cannot mix with the energy-rich electrons in the central portion 3 of the beam which is passed through the collimator structure.

In the construction illustrated in FIG. 1, it may be considered a disadvantage that the small surfaces of disc 2 projecting into the collimator aperture are encountered by full-energy electrons in the beam, so that there is some production of X-rays. However, because of the small surfaces involved, such X-rays have only a very slight effect and hence, can be disregarded.

FIG. 2 illustrates an embodiment of the invention wherein the desired result is attained solely by inclination of the inner surfaces of the two annular discs 1', 2'. In this embodiment, the inner surfaces 1a' and 2a' of the two discs have a frusto-conical configuration which jointly develop an unstepped surface convergent in the direction of passage of the beam 3' through the collimator. Thus, as in the case of FIG. 1, the inner surface 1a' of disc 1' is located further from the beam axis 4' than is the inner surface 2a'. As in the FIG. 1 construction, the discs 1' and 2' are made from metals having low and high atomic numbers, respectively. Because of the angles at which the inner surfaces 1a', 2a' of the collimator aperture are disposed with respect to the direction of passage of the electron beam, electrons deflected by diffusion, and proceeding in the direction indicated by the arrows 6', are partially trapped within the disc 1' and partially retarded in the disc 2', or deflected by a large amount with respect to the beam axis 4'. Low-energy electrons accordingly cannot mix with primary electrons rich in energy in the direction of passage of the beam.

An embodiment of the invention which combines both the stepped and solely inclined characteristics of the embodiments of FIGS. 1 and 2, respectively, is illustrated in

FIG. 3, which enables an even greater deflection to be imparted to those electrons which are not completely retarded in the disc having the high atomic number and would still emerge therefrom. In FIG. 3, the inner aperture 1a'' of disc 1'' has a frusto-conical configuration which converges in the direction of passage of the electron beam 3'' and the inner aperture 2a'' of disc 2'' also has a frusto-conical configuration but which diverges in the direction of passage of beam 3''. As in FIG. 1, the diameter of aperture 1a'' is somewhat larger than that of aperture 2a'' at their junction plane to thus develop a step between the two apertures at the junction. As in FIG. 1, the disc 1'' is made from a metal having a low atomic number and disc 2'' is made from a metal having a high atomic number. Since in the embodiment of FIG. 3, the stray electrons emanating from the retarded part 5'' of the field of radiation and proceeding in the directions indicated by arrows 6'', traverse a longer path in the disc 2'' than in the embodiment of FIG. 2, they are more strongly retarded in the disc 2'', and emerge at a larger angle to the beam axis 4'' of the masked-down beam 3''. It is accordingly impossible for the stray electrons emerging into the masked-down beam to reach the surface to be irradiated together with the primary electrons rich in energy which compose the beam 3''.

Since the higher specific weight of the tungsten causes it to retard high-velocity electrons of a given wavelength considerably more strongly than lead, and since tungsten also produces considerably greater lateral diffusion, it is advantageous to make the stepped part of the collimator aperture wholly or partially of tungsten. This embodiment is illustrated in FIG. 4 in which numeral 7 indicates an annular part of disc 2'' at the step made from tungsten. Otherwise, the construction in FIG. 4 is the same as in FIG. 3 and hence, corresponding components have been designated by the same reference characters. Thus, the remaining part of disc 2'' is made from a metal having a high atomic number such as lead, for example, and the disc 1'' is made from a metal having low atomic number such as, for example, aluminum.

The tungsten ring 7 which forms only part of the inner surface of the collimator aperture in disc 2'', is less expensive than would be a disc made entirely from tungsten, and is easier to make. The tungsten nevertheless, has a completely sufficient retarding and deflecting action on the stray electrons.

In order to mask-down an electron beam having an energy of about 35 m.e.v. with a collimator as shown in the embodiments of FIGS. 1 or 2 whereof the central aperture is, for example, 100 mm. in diameter in order to produce a beam of about 6° aperture angle, the aluminum disc 1 or 1' can be 25 mm. thick, and the lead disc 2, or 2' can be 10 mm. thick. Troublesome emergence of stray electrons is effectively prevented in this case if, in the arrangement shown in FIG. 1, the inner surface 1a of disc 1 at the step is set back about 6 mm. further from the beam axis 4 than is the distance of the inner surface 2a of disc 2 from the axis.

In the arrangement shown in FIG. 2, the same effect is attained if the distance of the inner surface 2a' of the lead disc 2' from the beam axis 4' at the side on which the beam emerges is about 6 mm. less than the distance of the inner surface 1a' of the aluminum disc 1' from the axis of the beam at the side on which the beam enters the collimator.

In the embodiments illustrated in FIGS. 3 and 4, it is expedient, assuming the same beam data with an energy level of about 35 m.e.v., to make the distance of the inner surface 1a'' of the aluminum disc 1'' from the beam axis 4'' at the side on which the beam enters the collimator about 6 mm. larger than at the junction plane at which disc 1'' lies against the lead disc 2''. The stepped-back part of the lead disc 2'' in FIG. 3, or of the tungsten ring 7 in FIG. 4 should, for its part be about 1 mm. nearer to the beam axis 4''.

For different beam energies and geometries, the most advantageous dimensions of collimators according to the invention may be determined by calculating the mean deflection of incident electrons in the metallic discs or layers 1 and 2, more particularly in the first disc 1 of the metal having a low atomic number.

In conclusion, the invention is not regarded as being limited to the several embodiments which have been described and illustrated. On the contrary, other possible surface configurations for the collimator aperture may also be conceived within the spirit of the invention. It is likewise possible to utilize the invention with electron-beam collimators made from a single substance or comprising more than two face-to-face discs or layers.

It is clear that a confined electron beam may be produced by using a collimator structure according to the invention, the energy of the beam being very little diffused, so that more advantageous curves of quantitative analysis in depth can be obtained when water or textiles are being irradiated. This increases substantially the action of the electron beam in depth as compared to undesired action at shallower depth. A further advantage resides in the fact that the improved collimator can be made without any additional expenditure.

I claim:

1. A high-velocity electron beam collimator structure comprising, a composite apertured body including at least first and second layers disposed in face-to-face relation, said layers being provided with apertures in axial alignment with the beam axis and through which the beam is passed, said first layer at the beam entrance side to said collimator being made from a metal having a low atomic number and said second layer at the beam emergence side from said collimator being made from a metal having a high atomic number, the surfaces defining the respective apertures in said first and second layers having a frusto-conical configuration divergent in the direction of passage of said beam, the aperture surface at the beam entrance side to said collimator being located further from the beam axis than is the aperture surface at the beam emergence side from said collimator, and the aperture surface of said first layer being set back in a direction away from said beam axis at the junction plane between said first and second layers to establish a stepped portion.

2. A high-velocity electron beam collimator structure comprising, a composite apertured body including at least first and second layers disposed in face-to-face relation, said layers being provided with apertures in axial alignment with the beam axis and through which the beam is passed, said first layer at the beam entrance side to said collimator being made from a metal having a low atomic number and said second layer at the beam emergence side from said collimator being made from a metal having a high atomic number, the surfaces defining the respective apertures in said first and second layers having a non-stepped frusto-conical configuration convergent in the direction of passage of said beam, the aperture surface at the beam entrance side to said collimator being located further from the beam axis than is the aperture surface at the beam emergence side from said collimator.

3. A high-velocity electron beam collimator structure comprising, a composite apertured body including at least first and second layers disposed in face-to-face relation, said layers being provided with apertures in axial alignment with the beam axis and through which the beam is passed, said first layer at the beam entrance side to said collimator being made from a metal having a low atomic number and said second layer at the beam emergence side from said collimator being made from a metal having a high atomic number, the surface defining the aperture in said first layer having a frusto-conical configuration convergent in the direction of passage of said beam and the surface defining the aperture in said second layer having a frusto-conical configuration divergent in the direction of passage of said beam, the aperture surface at the beam entrance side to said collimator being located further away

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from the beam axis than is the aperture surface at the beam emergence side from said collimator, and the aperture surface of said first layer being set back in a direction away from said beam axis at the junction plane between said first and second layers to establish a stepped portion. 5

4. A collimator structure as defined in claim 3 wherein the part of said second layer at said stepped portion is made from tungsten, the remainder of the second layer being made from lead.

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RALPH G. NILSON, *Primary Examiner.*