

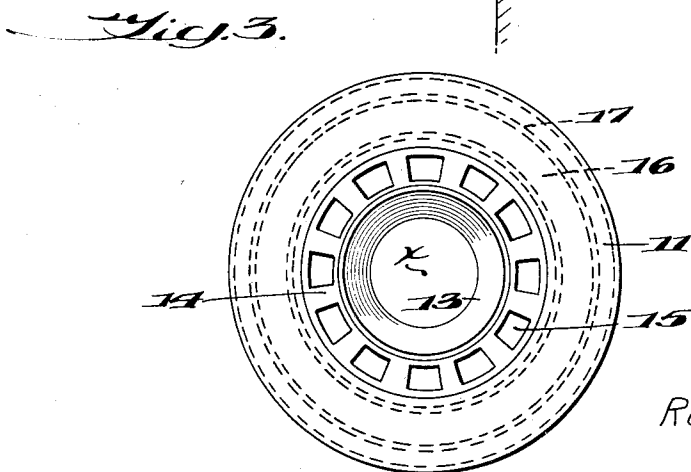
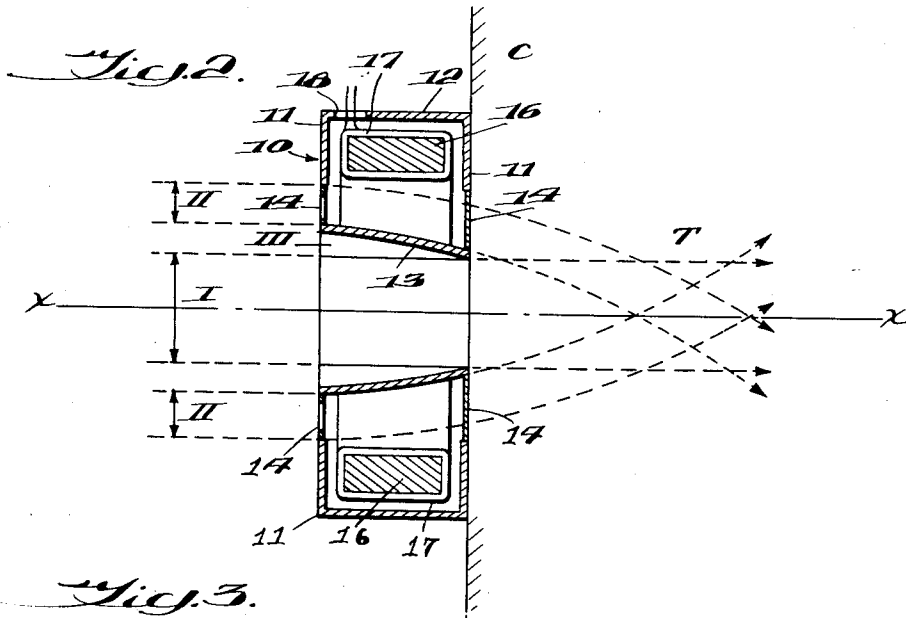
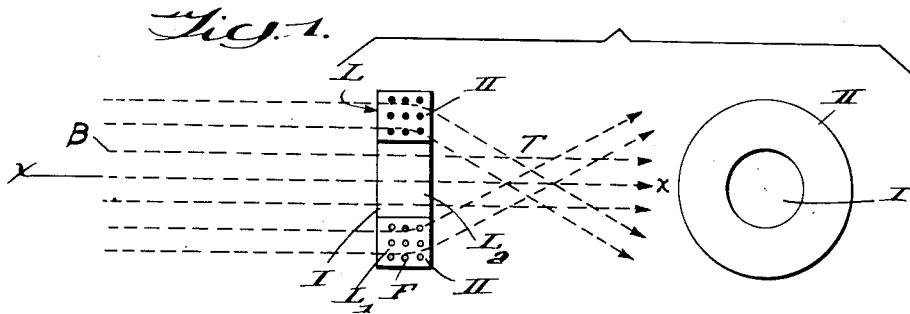
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ELECTRON BEAM LENS

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ELECTRON BEAM LENS

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The present invention relates to a lens for use with electron beams and in particular to an improved lens construction for focussing the electrons in the beam on a spot along the beam axis or at least concentrating the electrons in an area adjacent the axis.

The invention is particularly suited for use with apparatus in which a beam of high velocity electrons is employed for treating, by radiation, a portion of the human body located inwardly of the skin. It is known that high velocity electron beams have great penetrating power and, for example, an electron beam having a diameter of 10 cm. and a velocity factor of 30 Mev. impinging upon a human body will produce, at a depth of 8 cm., a dose which is about 90% of the dose produced at the surface.

An increase in the strength of the dose interiorly of the body can be achieved by use of a collective electron lens which is arranged between the electron beam and the subject to be radiated, and which effects a concentration of electrons within the subject at the desired depth. It is of particular advantage to apply the lens directly to the surface of the subject because the ratio of depth dose to surface dose becomes thus particularly large. This requires use of an electron lens with a comparatively large relative aperture; as a rule its focal length will have to be of the order of the diameter of the aperture.

The present invention has for an object to provide an improved electron lens construction and which avoids the difficulties in the past with prior designs by the fact that very strong magnetic fields were required for obtaining the electron concentrating effect and were also required to extend over a considerable cross-section for the particular case.

In general, this objective is attained by designing the lens in such manner that the electrons located only in an outer annular zone of the electron beam are deflected inwardly toward the beam axis by an annular magnetic field established only in that annular zone, while the electrons of the beam located inwardly of such zone pass uninterrupted, i.e. non-deflected through the lens aperture in a direction parallel to the lens axis. The improved construction enables one to obtain, with relatively smaller magnetic field strength, a collecting or concentrating effect which is sufficient for practical purposes in treating the interior of the human body. The improved electron lens is thus characterized in that it is provided with a central aperture through which the central portion of the electron beam passes in a non-influenced manner, i.e. in a direction parallel with the beam and lens axes which are coincident, this central aperture being surrounded by an annular toroidal space within which a magnetic field is produced and through which the outer portion of the electron beam is passed and deflected inwardly toward the common beam and lens axis.

The foregoing and other objects and advantages of the invention will become more apparent from the following detailed description of one practical embodiment thereof

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and from the accompanying drawings. In these drawings:

Fig. 1 is a somewhat diagrammatic view illustrating the principles of the invention;

Fig. 2 is a vertical central longitudinal sectional view of the improved lens; and

Fig. 3 is an end view as seen from the left end of Fig. 2.

The principles of the invention can be readily understood from the diagrammatic representation in Fig. 1. As indicated, the concentrating effect of the lens is toroidal in character and the toroidal lens is indicated by reference character L. This lens is arranged normal to and coincident with the axis $x-x$ of the high velocity electron beam B. An annular magnetic field F indicated by the dots in the toroidal cavity L1, i.e. the flux lines run in circular paths normal to the beam axis, causes those electrons passing through the toroidal cavity L to be deflected inwardly toward the beam axis, and these electrons, along with the electrons which pass through the central open portion L2 of the lens in a non-influenced manner directionwise, i.e. they pass through the lens parallel to the lens axis, meet in an area T of relatively high electron concentration within the body which is desired to be radiated.

A toroidal lens of practical construction operating in accordance with the principles graphically illustrated in Fig. 1 is shown in Figs. 2 and 3. With reference to these latter two views, it will be seen that the lens is formed as a toroidal shell 10. The radially outer portions of the shell, i.e. the radially outer portions 11 of the parallel spaced end walls and the outer cylindrical wall 12 connected therebetween, as well as the inner wall 13 connected to the end walls and which establishes a central aperture through the lens, are made from a relatively thick metallic material which is a good conductor of electric current. Copper or aluminum can be used for these thick wall portions.

The radially inner portions 14 of the end walls of the toroidal shell are made from a relatively thinner metallic material such as aluminum having a thickness of from 1 to 2 mm. and function as "windows" for the electrons which pass through the same without suffering any appreciable loss in energy. These end wall portions 14 can be imperforate or they can be provided with openings 15 as shown in Fig. 3 to facilitate unrestricted passage of the electrons therethrough. As an alternative construction, the end wall portions 14 can be constituted by a plurality of bars or plates arranged radially outward in the form of spokes and which thereby provide a somewhat larger open area therebetween for the electrons to pass through. If designed as spokes they should have a considerable extension in the axial direction so as to maintain a relatively low electrical resistance path there-through, and the spokes of one end wall should be aligned with the spokes of the other end wall so as to maintain the open areas therebetween in alignment for the free and uniform passage of electrons therethrough.

Within the interior of the toroidal shell 10 there is provided a toroidal core 16 of magnetic material arranged parallel to the shell axis, and a toroidal winding 17 is provided on the core. The terminal ends of winding 17 are passed through an opening 18 in the outer wall portion 12 for connection to a source of current. Since the current supply to coil 17 will be rather brief, intermittent pulses, it is preferable if the iron core 16 is made up from very thin laminar material or from ferrite, with a high permeability. For the same reason, any stray inductance should be kept as low as possible.

The magnetic field for deflecting the electrons in the toroidal cavity within shell 10 is preferably produced by using winding 17 as the "primary" winding of a transformer and the electrically conductive walls 11, 12, 13

and 14 which establish shell 10 as the "secondary" winding. Current flow of the order of 10^5 amperes is necessary to establish the required magnetic field intensity which is of several thousand gauss, and this current flows in the walls parallel to the direction of travel of the electrons. The resulting magnetic field established in the toroidal cavity acts to deflect the electrons which pass through the cavity in zone II to be deflected inwardly toward the common lens and electron beam axis.

The electrons in the central zone I of the electron beam pass through the central opening in the lens defined by the inner wall 13 uninfluenced as to direction. In use, the lens is preferably applied directly on the surface of the body C which is to be radiated, as indicated in the Fig. 2, the zone interiorly of the body on which the electrons are to be concentrated being indicated at T. The location of region T within the body can be varied by varying the intensity of the current used to excite the lens, i.e. the current flowing in winding 17 which in turn effects a corresponding variation in the strength of the deflecting magnetic field and a corresponding change in the electron deflection angle.

In view of the variable change in focal length of the lens effected by varying the intensity of the magnetic field, it is advisable to make the radial width of the window 14 on the electron exit side of the lens larger than on the electron entrance side. Thus, as seen in Fig. 2, the desired arrangement is effected by so configuring the inner wall 13 that it converges slightly in the direction of the electron path through the same, i.e. the diameter of the inner tubular wall 13 at the entrance for the electrons is larger than its diameter at the electron exit. In this manner the deflection angle for the electrons in the toroidal zone II may be varied by varying the current without those electrons striking against the thicker wall portions 11 of the shell.

Due to the converging configuration of the tubular inner wall 13, the diameter of wall 13 at the exit side of the lens establishes the diameter of the central zone I of the electron beam which passes through the lens uninfluenced as to direction of travel. Because of this, it will be seen from Fig. 2 that there will be a third zone III of the electron beam between zones I and II in which the electrons are essentially not utilized. This zone III can be used if desired for mechanical reinforcement of the lens, as may become necessary in view of the high dynamic stresses created when very high energizing currents are used.

In view of the relatively high voltage applied to winding 17, the opening 18 in shell 10 for the leads to such winding is preferably arranged in the interest of safety at the side of the lens away from the body C to be radiated. It is also preferable to ground the shell 10 at a point close to the body C and to electrically insulate the same from the body.

When the lens in accordance with the invention is used with a high velocity electron beam producing device of the magnetic induction type, commonly known as a Betatron, wherein streams of high velocity electrons are produced periodically with a frequency of the order of fifty times per second, it is of advantage if the electron lens is also energized periodically in synchronism with the periodic emission of electron streams from the Betatron. This periodic energization of the lens thus

reduces the electrical load on the same, as compared with continuous lens energization, but it is necessary with such an arrangement that the inductance of the lens winding 17 not be too high.

The periodic energization of the lens, i.e. of winding 17 can be effected from a supply source constituted by a condenser which is periodically charged and discharged. It is also possible to use a grid-controlled gaseous discharge tube, the grid control being correlated to the impulse producing means provided on the Betatron for effecting periodic emission of the accelerated electron streams therefrom. With such an inter-related control it is advisable to arrange an adjustable phase shifting device between the power source supplying the grid control pulses and the grid so that optimum operating conditions can be achieved empirically.

In conclusion, it is to be understood that the foregoing embodiment of the invention which has been described and illustrated is to be regarded as typical rather than limitative of construction, and hence various changes in the construction and arrangement of component parts of the improved electron lens may be made without, however, departing from the spirit and scope of the inventive concept as defined in the appended claims.

I claim:

1. An electron lens for concentrating a high velocity electron beam comprising a body member made from electrically conductive material, said body member having inner and outer radially spaced tubular walls, end walls connecting said inner and outer walls to establish a toroidal cavity therein, said inner tubular wall providing an aperture parallel to the beam axis and through which the central portion of said beam can pass parallel to the beam axis in a non-influenced manner, a toroidal core disposed within said toroidal cavity and arranged concentric with the beam axis, a toroidal winding on said core, and means energizing said winding thereby to induce a flow of current in the walls of said body member, said current producing an annular magnetic field through which an outer portion of said electron beam passes and is deflected thereby in a direction toward the beam axis.

2. An electron lens as defined in claim 1 wherein the radially inward portions of said end walls are made from relatively thin metallic material to thus constitute windows through which said electron beam can pass without appreciable loss of energy.

3. An electron lens as defined in claim 1 wherein the radially inward portions of said end walls are provided with openings to facilitate passage of the electrons into and out of said toroidal cavity.

4. An electron lens as defined in claim 1 wherein said inner tubular wall converges toward the axis in the direction of electron movement therethrough.

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