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(54) Electron accelerator

Elektronenbeschleuniger

Accélérateur d'électrons

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FR-A- 1 555 723 **FR-A- 2 684 512**

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Description

[0001] The present invention relates to an electron accelerator. It is used in the irradiation of various substances either directly by electrons or by x-rays obtained by conversion on heavy metal targets.

[0002] An electron accelerator is known which in general terms comprises a resonant cavity energized by a high frequency field source and the electron source able to inject electrons into the cavity. If certain phase and velocity conditions are satisfied the electrons are accelerated by the electric field troughout their passage through the cavity.

[0003] In accordance with this principle, in certain accelerator types the electron beam passes through the cavity several times, The apparatus then comprises an electron deflector receiving the once accelerated beam which then deflects it by approximately 180° and reinject it into the cavity for a further acceleration. A second deflector can again deflect the beam which has undergone two accelerations, so that it is made to pass through the cavity a third time and in this way obtains a third acceleration and so on. Such an apparatus is e. g. described in French Patent 15 55 723 entitled "100 MeV continuously operating electron accelerator".

[0004] This type of accelerator suffers from the following disadvantage. During the first injection into the cavity the electron beam follows a path coinciding with the axis thereof. Along this path the electric field only has a single component directed along the axis. Thus, acceleration of the electrons takes place and there is no deflection of the beam because there is no transverse component of the electric field. However, during the second passage through the cavity, the electron beam takes a path which is no longer directed along said axis. A magnetic component perpendicular to the axial component of the electric field can act on the electron beam, so that the electrons are deflected. This deflection will depend on the phase of the electromagnetic field which heads to a dispersion of the beam and consequently part will be lost on the walls of the cavity. Moreover, this parasitic phenomenon increases during multiple passages.

[0005] However, multiple passage accelerators are known, which obviate this problem as a result of a special deflector structure. According to this variant, e. g. described in US Patent No. 3.349.335, the electrons perform a complete loop outside the cavity and are reinjected into its axis.

[0006] According to another variant described in FR-A-11 36 936, acceleration takes place in resonant cavity and after each passage the electrons are deflected outside the vavity so that they pass round the same and are re-injected into the.acceleration axis.

[0007] According to yet another variant, sometimes called the Duotron, the electron beam is reflected on itself and thus performs an outward and return travel along the cavity axis.

[0008] In these improved variants, the electron beam, during this multiple passage, still follows the path for which the deflecting fields are zero (the electric field is parallel to the velocity vector of the electrons and is opposite directed).

[0009] However, these apparatus have a complex construction. In the first two, the various electron paths have a common branch coinciding with the cavity axis, but the other branches are outside the cavity which increases the complexity and overall dimensions of the apparatus. In the last, there is a limitation to a single and outward and return path of the beam and it is not easy to solve the problem of reflecting the electron back on themselves.

[0010] In accordance with Patents FR-A-11 36 936 and US 5.107.221 for the purpose of accelerating it is proposed to use a half-wavelength coaxial cavity with the electron beam injection to the median plane of the cavity along ist diameter and re-injection after passing the deflector at the same median plane along different diameter. These multiple passages are performed until required energy is obtained.

[0011] The advantage of this apparatus is in complete absence of the magnetic component of high frequency field at the beam accelerating area, and deflectors location unification.

[0012] The disadvantage of this apparatus is in necessity of high rate of beam acceleration even at passing the first high frequency accelerating gap from external conductor to internal one (about 500 - 800 kV). The reason is that the electron velocity is to be close to that of the light for providing synchronization of the electrons travel with alternation of the polarity of the electric field in the gap between external and internal conductors. In view of this, there are observed 200 - 300 kW losses of capacity in the cavity. To garantee high efficiency of gaining of energy by the electrons in the first gap between external and internal conductors at the electrons travel path along the first diameter, it is nessessary to provide this apparatus with high initial energy and pulse velocity of the electron current, which is injected by the electron source.

[0013] The present invention aims to avoid all disadvantages mentioned above. For this purpose it is proposed an electron accelerator benefitting from the effect of multiple passages through the cavity and incorporating absence of deflecting high frequency magnetic field along the electrons paths through the cavity, and which makes it possible to use low - rate of the beam accelerating along each passage through the cavity.

[0014] In accordance with the invention the electron accelerator includes a source of electrons and a toroidal cavity, having a rotation axis. Said toroidal cavity is connected with a high frequency source which excites the azimuthal homogeneous distribution for electromagnetic fields in the cavity. On the accelerating radius the electric field component is parallel to said rotation axis of the cavity and the magnetic field component is equal to zero. Said source of electrons injects the electron beam into the cavity along a first axis and the beam crosses the cavity without changing the direction of motion. For the purpose of multiple acceleration in the cavity deflectors are placed outside the cavity and entrances and exits of the deflectors are located on axes of the beam crossing the cavity which are parallel to the rotation axis of the cavity and, different from each other, disposed on the cylindrical surface with an accelerating radius and its rotation axis identical to said rotation axis.

[0015] The characteristics of the invention will be defined more clearly with the description hereunder. This description refers to drawings attached thereto wherein

Fig. 1	displays a toroidal cavity which resonates at the main harmonics with the electric field parallel to the rotation axis,
FIG. 2	illustrates a principle of multiple acceleration of the electron beam at the toroidal cavity with the electric field parallel to the rotation axis and
FIG. 3	illustrates geometrical characteristics of the electron trajectories inside the apparatus.

[0016] FIG. 1(a) displays a toroidal cavity TC having two identical flat ring-shaped conductors 1 and 2 with an rotation axis A, which are symmetrically located with respect to a median plane PM, the conductor 3, closing the conductors 1 and 2 to each other from the external side and having the same rotation axis, and the conductor 4, closing the conductors 1 and 2 from the internal side and having the same rotation axis. This cavity TC is energized by a high frequency source SHF via the coupling loop 5.

[0017] The cacity TC has the rotation axis A and the median plane PM perpendicular to the rotation axis A and located at the center of the distance between the conductors 1 and 2. The conductors 1 and 2 are symmetrically placed with respect to the median plane PM. Among all possible resonance modes of such a cavity TC there is one with the electric field E, parallel to the rotation axis A of the cavity TC and with the magnetic field M, perpendicular to this rotation axis A. For this mode the electric field E and the magnetic field M have no rotation variation.

[0018] FIG. 1(b) displays the part of the cavity TC, which contains the external sides of the conductors 1 and 2 and the conductor 4. Toroidal cavity TC inside the conductor 4 appears to be an inductivity, while the volume between the ring-shaped conductors 1 and 2 appears to be a capacity. High frequency current goes from one conductor to another via the conductor 4. This part of the cavity TC has resonant frequency with the magnetic field M, having only azimuthal component.

[0019] FIG. 1(c) displays the part of the cavity TC, which contains the internal conductor 3 and the internal sides of the conductors 1 and 2. This part of the cavity TC has resonance frequency with the magnetic field M symmetrical with respect to the rotation axis A. If the resonance frequencies of the external and internal parts of the cavity TC coincide, then their aggregation into the cavity TC will have the same resonance frequency, and in the point of connection of the internal and external sides of the conductors 1 and 2 the high frequency currents will be absent and the magnetic field M will be equal to zero, while the electric field E between the conductors 1 and 2 will have its maximum value. The radius of the maximum of the electric field E between the conductors 1 and 2, absence of the magnetic component and coincidence of the resonance frequencies of the external and internal sides of the cavity TC are provided by increase of the cross-section of the cavity TC inside the conductor 4 with respect to the cross-section of the cavity TC inside the conductor 3. As far as in this case there is no magnetic field component in the cavity TC between the conductor 1 and 2 along the radius Ra, then the electron current is not subjected to to any deflection force. As far as in the cavity TC between the conductors 1 and 2 along the radius Ra the electric field E is of the maximum value and is directed in parallel direction to the rotation axis A of the cavity TC, then the acceleration of the electrons is possible by means of multiple passages of the beam along the axis of the symmetry of the cavity TC.

[0020] In FIG. 2 the scheme of the electron beam acceleration in the toroidal cavity TC is shown.

[0021] In part (a) of FIG. 2 it is depicted the azimuthal section of the acceleration structure. This section goes through the point in which the electron beam crosses the median plane PM on the radius Ra of the electic field maximum. The invention operates as follows. The electron source ES emits an electron beam F in parallel direction to the cavity rotation axis A and perpendicular to the median plane PM along the axis A1, located on the radius Ra of the electric field maximum between the conductors 1 and 2. The beam F enters the cavity through the opening 10 in the conductor 1, is accelerated and leaves the cavity TC through the opening 11 in the conductor 2. Then it goes to the entrance 111 of a deflector D1 without changing the direction (without leaving axis A1). The deflector D1 deflects the beam F by 180° and directs the beam F through an exit 200 to the cavity TC along the axis A2 in parallel direction with respect to the cavity rotation axis A, located on the radius Ra of the maximum of the electric field E between the conductors 1 and 2. Azimuthal directions of the axes A2 and A1 differ by an angle Θ1. While passing the cavity TC between entrance 20 and exit 21, the electron beam F is accelerated by the electric field E, if the phase conditions are fulfilled. Leaving the cavity TC through the opening 21, the electron beam F travels along the axis A2 until it reaches the entrance 211 of the deflector D2. The deflector D2 deflects the beam F by 180° and directs the beam F through the exit 300 to the cavity TC along the axis A3 in parallel direction with respect of the cavity rotation axis A, located on the radius Ra of the maximum- of the electric field E between the conductors 1 and 2. Azimuthal directions of the axes A2 and A3 differ by an angle Θ2. While passing the cavity TC between entrance 30 and exit 31, the electron beam F is accelerated by the electric field E, if the phase conditions are fulfilled. While traveling along the axis A3 after leaving the cavity TC through the exit 31, the beam F is introduced to the entrance 311 of the deflector D3. The deflector D3 deflects the beam F by 180° and directs the beam F through the exit 400 to the cavity TC along the axis A4 in parallel direction with respect to the cavity rotation axis A, located on the radius Ra of the maximum of the electric field E between the conductors 1 and 2. Azimuthal directions of the axes A3 and A4 differ by an angle Θ3. While passing the cavity TC between entrance 40 and exit 41, the electron beam F is accelerated by the electric field E, if the phase conditions are fulfilled. If no succeeding deflectors are installed, then the acceleration process is completed and the beam F goes along the axis A4 to destination. If succeeding deflectors are installed, the acceleration can be proceeded.

[0022] In part (b) of FIG. 2 there is depicted the median plane PM section of the accelerator on the basis of toroidal cavity TC with the electric field E parallel to the cavity rotation axis A. Via the coupling loop 5 the toroidal cavity TC together with the conductors 3 and 4 is supplied by the high frequency source SHF with the energy at the frequency, equal to the resonance frequency of the cavity TC. On the radius Ra is created the maximum of tension with the electric field direction parallel to the rotation axis A and perpendicular to the median plane PM. The electron source ES is located outside the cavity TC and injects the beam F along the axis A1, perpendicular to the median plane PM and located on the radius Ra. After acceleration in the cavity TC, the beam F keeps the travel direction along the axis A1 and is introduced to the deflector D1 placed at the side of the cavity TC opposite to the electron source ES. The beam F is turned in the plane of the deflector PD1 by the angle 180° and is redirected to the cavity TC along the axis A2, which is parallel to the rotation axis A on the radius Ra and which differs from the axis A1 by the angle Θ1. If the synchronism conditions are fulfilled, the beam F crosses the cavity TC, is accelerated and, keeping the travel along the axis A2, is introduced to the entrance of the deflector D2, placed on the opposite side with respect to the deflector D1.

[0023] The beam F is turned in the plane of the deflector PD2 by the angle 180° an is redirected to the cavity TC along the axis A3, which is parallel to the rotation axis A on the radius Ra and which differs from the axis by the angle Θ2. If the synchronism conditions are fulfilled the beam F crosses the cavity TC, is accelerated and, keeping the travel along the axis A3, is introduced to the entrance of the deflector D3, placed on the opposite side with respect to the deflector D2. The beam F is turned in the plane of the deflector PD3 by the angle 180° and is redirected to the cavity TC along the axis A4, which is parallel to the rotation axis A on the radius Ra and which differs from the axis A3 by the angle Θ3. If the synchronism conditions are fulfilled, the beam F crosses the cavity TC and is accelerated. The succeeding deflectors are installed in the same fashion.

[0024] As the principle of the accelerating according to the invention has now been defined, a few practical questions, such as synchronism conditions, beam focusing and shunt impedance will be considered in more details below.

[0025] The electron beam F injected by the electron source ES is accelerated at the cavity TC in the gap between the conductors 1 and 2. During the period of the beam motion outside the cavity TC in the direction of the deflector D1 and from the deflector D1 to the gap between the conductors 2 and 1, the direction of the electric field in the cavity TC must be changed to opposite. After that, during the period of time of the beam travel to the deflector D2 and back to the accelerating gap of the cavity TC between the conductors 1 and 2, the direction of the electric field E must be changed to opposite once more. The synchronism conditions are the same for the succeeding accelerations. If the electrons velocity is V, the relative electrons velocity is $\beta = V/c$, where c is the speed of light, and α is the length of the electron path from the median plane PM to the deflector and back, then the time, nessesary for the electrons to cover the path α must be equal to the half-period of oscillations in the cavity TC plus any number K of the integer period of oscillations, so that the following synchronism conditions are obtained:

$$- \alpha/V = T/2 + KT \text{ or } \alpha = \lambda(1/2 + K)\beta,$$

where λ is the wavelength. For example, if β = 0,7 (200keV), λ = 3m and K = 0, then α is 1,05m, and if β = 0,95 (1200keV), then α = 1,42m.

[0026] In order to make the apparatus dimension smaller, it is reasonable to use K = 0. However, if the electrons velocity V is much smaller than the speed of light, or it is necessary to keep some room between the cavity and the deflector in order to install there focusing elements, one has to use K = 1 or even more. If the operational frequency of the cavity is high and, in correspondence, the wavelength λ is small, it can also be reasonable to use K = 1 or more.

[0027] In part (a) of FIG. 3 the electron trajectory between two points of crossing the median plane PM is presented. The angle between the median plane PM and the electron beam trajectory at their crossing equals to 90°. If Rc is the radius of the curvature of the electrons travel path in one of the deflectors, and L is the distance between the median plane PM of the cavity TC and an entrance CD and an exit SD from the deflector, then the length of the electrons path between two crossings of the median plane is:

$$\alpha = 2L + \pi Rc$$

[0028] Thus, the synchronism conditions are:

$$(2L + \pi Rc) = \lambda(1/2 + K)\beta$$

[0029] If $f = 100$ MHz, $\lambda = 3m$, $\beta = 1$, $K = 0$, $Rc = 0{,}05m$, then $L = 0{,}67m$.

[0030] In part of FIG. 3 (b) there is presented the view along the rotation axis A of the electron beam trajectory. So far, the motion in the deflectors takes place from one axis A1 on the radius Ra to other axis A2 of the same radius along a chord of the length of 2Rc. If along the circle of the radius Ra there are installed n deflectors, then the electron beam F will pass the accelerating gap and undergoes n+1 accelerations. If the radius Rc is equal for all the deflectors, a step of shifting along the azimuth of the axis of the electron beam motion after each of the deflectors is:

$$\Theta = 2\pi/n+1 \text{ and } Rc = Ra \sin\Theta/2$$

[0031] If $Ra = 0{,}75m$, $\lambda = 3m$ and $\beta = 1$, one has:

$n = 39$, $\Theta = 9{,}0^\circ$, $Rc = 5{,}88cm$, $L = 65{,}7cm$,
$n = 29$, $\Theta = 12^\circ$, $Rc = 7{,}83$ cm, L 62,7 cm.

[0032] In order to increase multiplicity of acceleration one has to have as large value of Ra as possible.

[0033] Beam focusing is necessary to keep a certain beam dimensions in the vicinity of the central trajectory. Focusing elements are placed outside the cavity between the cavity and the deflector. It is possible to use magnetic quadrupole lenses for this purpose. However, the better solution is to use solenoids with magnetic field, directed along the beam trajectory.

[0034] Focusing effect of the solenoids is proportional to the length of the magnetic field action and square of the magnetic field value. In the relativistic case it is inverse proportional to the square of the electrons velocity. As far as at solenoids regular location the mean beam dimension slightly depends on the focusing effect of each of the solenoids, accuracy of the choice of this effect for the solenoids is low.

[0035] Electric quality of the cavity is usually characterized by effective shunt resistance Rsh as the ratio of the square of the gained energy of the electrons at- one passage through the cavity (in eV) to the energy dissipated in the conductors. The shunt resistance of the invented toroidal cavity at the frequency of 100 MHz with the radius of axes of the entrances and exits of the beams to the cavity and deflectors of Ra = 0,75m, and axial gap between the conductors 1 and 2 of 0,16m, is $Rsh \approx 1{,}7\ M\Omega$. At these conditions to obtain the electrons energy of 10 MeV with 40 crossings of the accelerating gap, the energy, dissipated in the conductors is 37 kW.

[0036] For one and the same final electrons energy the energy dissipated in the cavity is reverse proportional to the square of the number of the beam passages through the cavity. That is why it is reasonable to use large number of passages, but it necessitates increase of the energy supply of the deflectors.

Claims

1. Electron accelerator, including a source of electrons (ES) and a toroidal cavity (TC), having a rotation axis (A), said toroidal cavity (TC) being connected with a high frequency source (SHF) which excites the azimuthal homogeneous distribution for electromagnetic fields (E) in the cavity (TC), on the accelerating radius (Ra) of the cavity (TC) the electric field component (E) being parallel to said rotation axis (A) of the cavity (TC) and the magnetic field component (M) being equal to zero and said source of electrons (ES) injecting the electron beam (F) into the cavity (TC) along a first axis (A1) and the beam (F) crossing the cavity (TC) without changing the direction of motion and for the purpose of multiple acceleration in the cavity (TC) deflectors (D1, D2, D3) being placed outside the cavity (TC) and entrances (111, 211, 311) and exits (200, 300, 400) of the deflectors (D1, D2, D3) being located on axes (A1, A2, A3) of the beam (F) crossing the cavity (TC) which are parallel to the rotation axis (A) of the cavity (TC) and, different from each other, disposed on the cylindrical surface with an accelerating radius (Ra) and its rotation axis identical to said rotation axis (A).

2. Electron accelerator as recited in claim 1, **characterized in that** said toroidal cavity (TC) - includes two flat ring-shaped conductors (1, 2) with said rotation axis (A) and symmetrical with respect to the median plane (PM), which is perpendicular to said rotation axis (A), and larger radius ends of said conductors (1, 2) are closed by an external conductor (4), which has the same said rotation axis (A), and smaller radius ends of said conductors (1, 2) are closed by an internal conductor (3), having the same rotation axis (A), and said conductors (1, 2, 3, 4) form the toroidal cavity (TC), and the dimensions of said internal and external conductors (3, 4) are such, that the electric field (E) between said ring-shaped conductors (1, 2) at the accelerating radius (Ra) is parallel to said rotation axis (A) and perpendicular to said median plane (PM) and to the surface of said ring-shaped conductors (1, 2) and the magnetic field component (M) equals to zero.

3. Electron accelerator as recited in claim 1 or 2, **char-**

acterized in that said electron beam (F), being injected to said cavity (TC) along a first axis (A1), which is parallel to said rotation axis (A) and placed on said acceleration radius (Ra), is subjected to first acceleration while traveling between said ring-shaped conductors (1, 2) along said first axis (A1), leaves the cavity (TC) and keeps motion along said first axis (A1) up to it is deflected, for which a first deflector (D1) is placed outside said cavity (TC), receiving the electron beam (F) after said first acceleration at the motion along said first axis (A1), and deflecting said beam (F) for re-injection to said cavity (TC) in the direction of a second axis (A2), which is parallel to said rotation axis (A) of said cavity (TC) and is placed on said accelaration radius (Ra) and is different from said first axis (A1), and said electron beam (F) is subjected to second acceleration at traveling through said cavity (TC) between said ring-shaped conductors (1, 2), and the electron beam (F) after said second acceleration moves along said second axis (A2) up to the second deflector (D2), placed outside the cavity (TC), and said second deflector (D2) receives the electron beam (F) and deflects said beam (F) for next re-injection to said cavity (TC) in the direction of a third axis (A3), which is parallel to said rotation axis (A) of said cavity (TC) and is placed on said accelerating radius (Ra) and is different from said first and second axes (A1, A2), and succeeding deflectors are placed in the same fashion, so that directions of the electron beam (F) motion through said cavity (TC) and between succeeding deflectors are placed on axes, which are parallel to said rotation axis (A) and different from each other and placed on said accelerating radius (Ra).

4. Electron accelerator as recited in one of the foregoing claims, wherein focussing elements are installed between the cavity (TC) and the deflectors (D1,PD1; D2,PD2; D3,PD3; PD).

Patentansprüche

1. Elektronenbeschleuniger, der eine Elektronenquelle (ES) und einen torusförmigen Hohlraum (TC) mit einer Rotationsachse (A) umfaßt, wobei der torusförmige Hohlraum (TC) mit einer Hochfrequenzquelle (SHF) verbunden ist, welche die azimutal homogene Verteilung der elektromagnetischen Felder (E) im Hohlraum (TC) anregt; beim Beschleunigungsradius (Ra) des Hohlraumes (TC) ist die elektrische Feldkomponente (E) parallel zur Rotationsachse (A) des Hohlraumes (TC) ausgerichtet, die magnetische Feldkomponente (M) ist gleich null und die Elektronenquelle (ES) injiziert den Elektronenstrahl (F) in den Hohlraum (TC) in Richtung einer ersten Achse (A1), und der Strahl (F) durchquert den Hohlraum (TC), ohne die Richtung seiner Bewegung zu ändern, und zum Zwecke einer mehrmaligen Beschleunigung im Hohlraum (TC) sind außerhalb des Hohlraumes (TC) Deflektoren (D1, D2, D3) angeordnet, und Eintrittsstellen (111, 211, 311) und Austrittsstellen (200, 300, 400) der Deflektoren (D1, D2, D3) sind auf Achsen (A1, A2, A3) des Strahls (F), der den Hohlraum (TC) durchquert, angeordnet, die parallel zur Rotationsachse (A) des Hohlraumes (TC) ausgerichtet und auf der zylindrischen Oberfläche im Beschleunigungsradius (Ra) unterschiedlich zueinander verteilt sind, dessen Rotationsachse identisch mit der Rotationsachse (A) ist.

2. Elektronenbeschleuniger nach Anspruch 1, **dadurch gekennzeichnet, dass** der torusförmige Hohlraum (TC) zwei flache, ringförmige Leiter (1, 2) mit der Rotationsachse (A) umfaßt, die in Bezug auf die rechtwinklig zur Rotationsachse (A) liegende Medianebene (PM) symmetrisch verlaufen, und dass die Enden der Leiter (1, 2) mit dem größeren Radius durch einen äußeren Leiter (4) miteinander verbunden sind, der dieselbe Rotationsachse (A) hat, und dass die Enden der Leiter (1, 2) mit dem kleineren Radius durch einen inneren Leiter (3) miteinander verbunden sind, der dieselbe Rotationsachse (A) hat, und dass die Leiter (1, 2, 3, 4) den torusförmigen Hohlraum (TC) bilden, und dass die Abmessungen der äußeren und inneren Leiter (3, 4) so sind, dass das elektrische Feld (E) zwischen den ringförmigen Leitern (1, 2) beim Beschleunigungsradius (Ra) parallel zur Rotationsachse (A) und rechtwinklig zur Medianebene (PM) verläuft und in Richtung zur Oberfläche der ringförmigen Leiter (1, 2) gerichtet ist, und dass die magnetische Feldkomponente (M) gleich null ist.

3. Elektronenbeschleuniger nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Elektronenstrahl (F), der in den Hohlraum (TC) in Richtung einer ersten Achse (A1) injiziert wird, die parallel zur Rotationsachse (A) liegt und im Beschleunigungsradius (Ra) angeordnet ist, auf seiner Bahn zwischen den ringförmigen Leitern (1, 2) in Richtung der ersten Achse (A1) einer ersten Beschleunigung unterworfen wird, den Hohlraum (TC) verläßt und seine Bewegungsrichtung in Richtung der ersten Achse (A1) beibehält bis er abgelenkt wird, wozu außerhalb des Hohlraumes (TC) ein erster Deflektor (D1) angeordnet ist, der den Elektronenstrahl (F) empfängt, nachdem dieser während der Bewegung entlang der ersten Achse (A1) beschleunigt wurde und den Strahl (F) für eine erneute Injektion in den Hohlraum (TC) in Richtung einer zweiten Achse (A2) ablenkt, die parallel zur Rotationsachse (A) des Hohlraumes (TC) gerichtet und im Beschleunigungsradius (Ra) angeordnet ist und die von der ersten Achse (A1) verschieden ist, und dass der Elektronenstrahl (F) auf der Bahn durch den Hohlraum (TC) zwischen den ringförmigen Leitern (1, 2) einer zweiten Beschleunigung unterworfen wird, und dass der Elektronenstrahl (F) sich nach der zweiten Beschleunigung in Richtung der zweiten Achse (A2) bis zum zweiten Deflektor (D2) bewegt, der außerhalb des Hohlraumes (TC) angeordnet ist, und dass der zweite Deflektor (D2) den Elektronenstrahl (F) empfängt und den Elektronenstrahl (F) für die nachfolgende erneute Injektion in den Hohlraum (TC) in Richtung einer dritten Achse (A3) ablenkt, die parallel zur Rotationsachse (A) des Hohlraumes (TC) gerichtet und im Beschleunigungsradius (Ra) angeordnet ist und die von den ersten und zweiten Achsen (A1, A2) verschieden ist, und dass aufeinanderfolgende Deflektoren auf die gleiche Art und Weise angeordnet sind, so dass die Richtungen der Bewegung des Elektronenstrahls (F) durch den Hohlraum (TC) und zwischen den aufeinanderfolgenden Deflektoren auf Achsen liegen, die parallel zur Rotationsachse (A) verlaufen und voneinander verschieden und im Beschleunigungsradius (Ra) angeordnet sind.

4. Elektronenbeschleuniger nach einem der vorhergehenden Ansprüche, wobei fokussierende Elemente zwischen dem Hohlraum (TC) und den Deflektoren (D1, PD1; D2, PD2; D3, PD3; PD) installiert sind.

Revendications

1. Accélérateur d'électrons comprenant une source d'électrons (ES) et une cavité toroïdale (TC) ayant un axe de rotation (A), ladite cavité toroïdale (TC) étant connectée avec une source de haute fréquence (SHF), laquelle excite la distribution azimutale homogène pour des champs électromagnétiques (E) dans la cavité (TC), le vecteur de .champ électrique (E) étant parallèle au susdit axe de rotation (A) de la cavité (TC) et le vecteur de champ magnétique (M) étant égal à zéro sur le rayon d'accélération (Ra) de la cavité (TC), et ladite source d'électrons (ES) injectant le faisceau d'électrons (F) dans la cavité (TC) le long du premier axe (A1) et le faisceau (F) traversant la cavité (TC) sans changer la direction du déplacement et, aux fins d'une accélération multiple dans la cavité (TC), des déflecteurs (D1, D2, D3) étant placés hors de la cavité (TC), et les entrées (111, 211, 311) et les sorties (200, 300, 400) des déflecteurs (D1, D2, D3) étant situées sur les axes (A1, A2, A3) du faisceau (F) traversant la cavité (TC) qui sont parallèles à l'axe de rotation (A) de la cavité (TC) et, de façon différente les uns des autres, disposés sur la surface cylindrique avec un rayon d'accélération (Ra) et son axe de rotation identique au susdit axe de rotation (A).

2. Accélérateur d'électrons selon la revendication 1, **caractérisé en ce que** la cavité toroïdale (TC) comprenne deux conducteurs annulaires plats (1, 2) avec ledit axe de rotation (A) et symétriques relativement au plan médian (PM), lequel est perpendiculaire au susdit axe de rotation (A), et **en ce que** les extrémités du plus grand rayon des susdits conducteurs (1, 2) sont fermées par un conducteur externe (4), lequel a le même susdit axe de rotation (A), et **en ce que** les extrémités du plus petit rayon des susdits conducteurs (1, 2) sont fermées par un conducteur interne (3), ayant le même axe de rotation (A), et **en ce que** lesdits conducteurs (1, 2, 3, 4) forment la cavité toroïdale (TC), et avec les dimensions des susdits conducteurs interne et externe (3, 4) étant telles que le champ électrique (E) entre lesdits conducteurs annulaires (1, 2) sur le rayon d'accélération (Ra) est parallèle au susdit axe de rotation (A) et perpendiculaire au susdit plan médian (PM) et à la surface des susdits conducteurs annulaires (1, 2), et le composant du champ magnétique (M) étant égal à zéro.

3. Accélérateur à électrons selon les revendications 1 ou 2, **caractérisé en ce que** ledit faisceau d'électrons (F), étant injecté dans ladite cavité (TC) le long d'un premier axe (A1), lequel est parallèle au susdit axe de rotation (A) et placé sur ledit rayon d'accélération (Ra), subit une première accélération pendant qu'il passe entre les conducteurs annulaires (1, 2) le long du dit premier axe (A1), quitte la cavité (TC) et poursuit sa trajectoire le long du dit premier axe (A1) jusqu'à ce qu'il soit dévié, en vue de quoi un premier déflecteur (D1) est placé hors de ladite cavité (TC), recevant le faisceau d'électrons (F) après la susdite première accélération lors du trajet le long.du dit premier axe (A1) et faisant dévier ledit faisceau (F) pour qu'il soit réinjecté dans ladite cavité (TC) dans là direction d'un second axe (A2), lequel est parallèle au susdit axe de rotation (A) de ladite cavité (TC) et est placé sur ledit rayon d'accélération (Ra) et est différent du dit premier axe (A1), et ledit faisceau d'électrons (F) subissant une seconde accélération en traversant ladite cavité (TC) entre lesdits conducteurs annulaires (1, 2) et après la seconde accélération ledit faisceau d'électrons (F) se déplaçant suivant ledit second axe (A2) jusqu'au second déflecteur (D2), placé hors de la cavité (TC), et ledit second déflecteur (D2) recevant le faisceau d'électrons (F) et faisant dévier ledit faisceau (F) pour la prochaine réinjection dans ladite cavité (TC) dans la direction d'un troisième axe (A3), lequel est parallèle au susdit axe de rotation (A) de ladite cavité (TC) et est placé sur le susdit rayon d'accélération (Ra) et est différent des susdits premier et second axes (A1, A2), et des déflecteurs qui se suivent étant placés de la même manière, de telle sorte que le déplacement du faisceau d'élec-

trons (F) à travers la cavité (TC) et entre les déflecteurs se succédant a lieu dans la direction des axes, lesquels sont parallèles au susdit axe de rotation (A) et différents entre eux et placés sur ledit rayon d'accélération (Ra).

4. Accélérateur d'électrons selon l'une des revendications précédentes, **caractérisé en ce que** des éléments de focalisation sont installés entre la cavité (TC) et les déflecteurs (D1, PD1 ; D2, PD2 ; D3, PD3 ; PD).

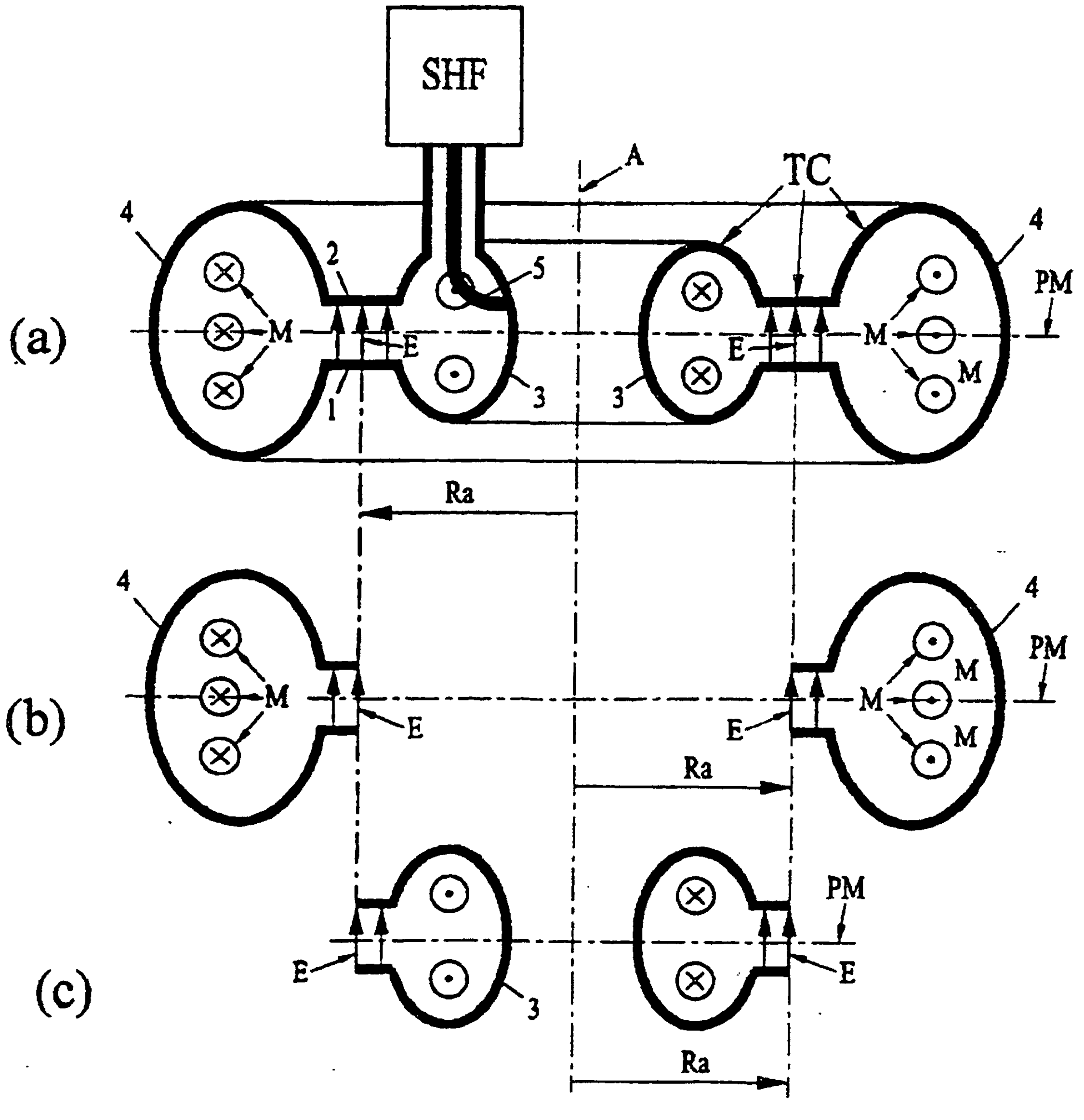

FIGURE 1.

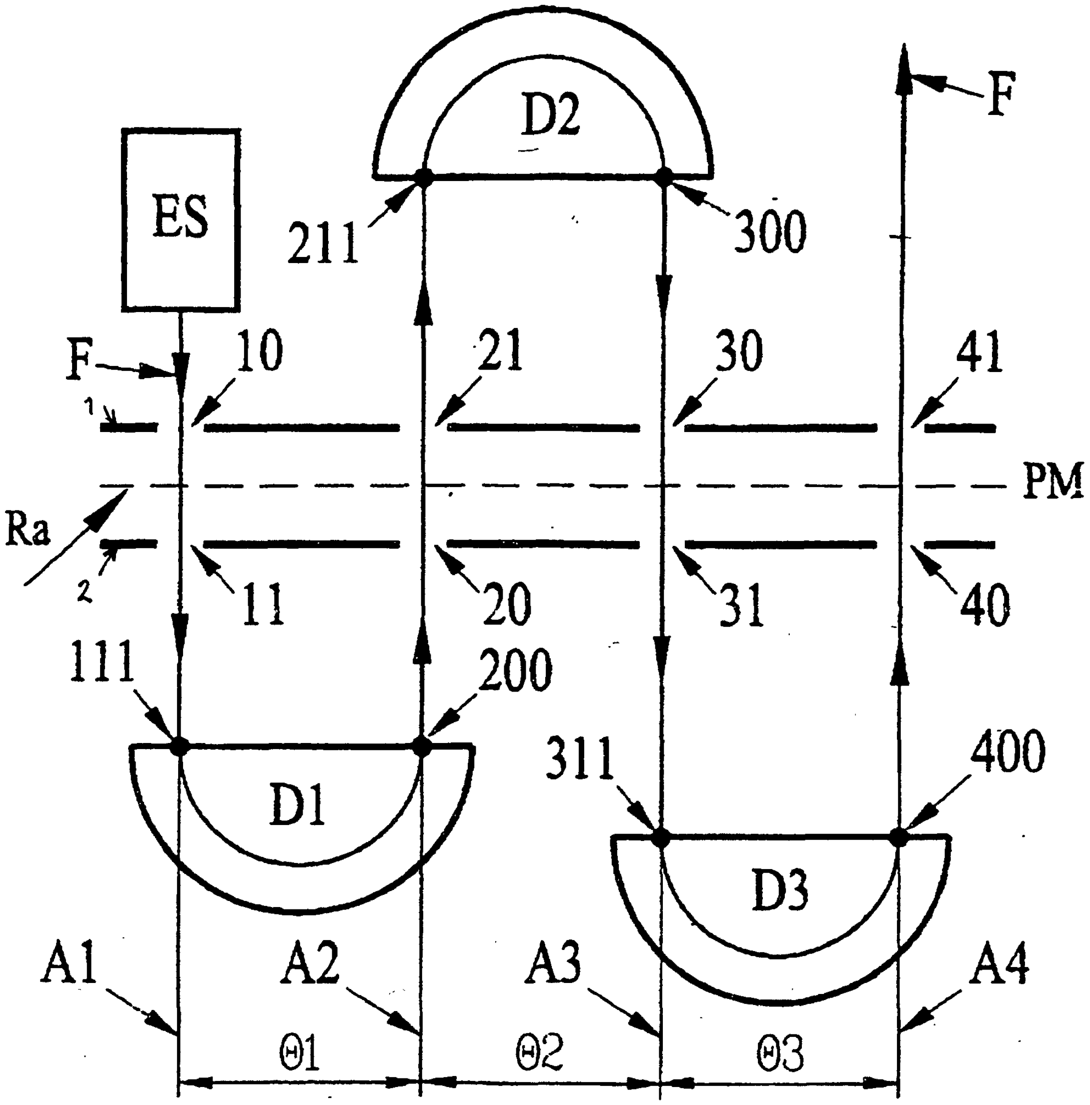
D2
F
ES
211
300
F
10
21
30
41
1
PM
Ra
2
11
20
31
40
111
200
311
400
D1
D3
A1
A2
A3
A4
Θ1
Θ2
Θ3

FIGURE 2 (a).

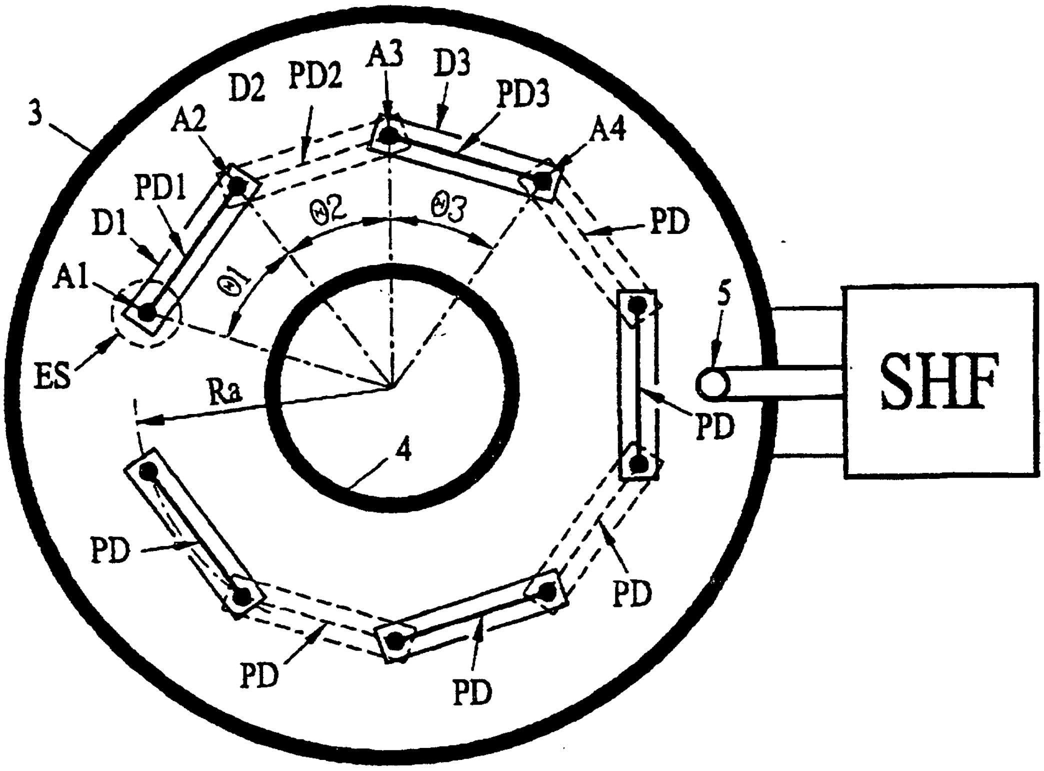
3
A2
D2
PD2
A3
D3
PD3
A4
PD1
D1
A1
ES
Θ1
Θ2
Θ3
PD
5
SHF
Ra
PD
4
PD
PD
PD
PD

Figure 2 (b)

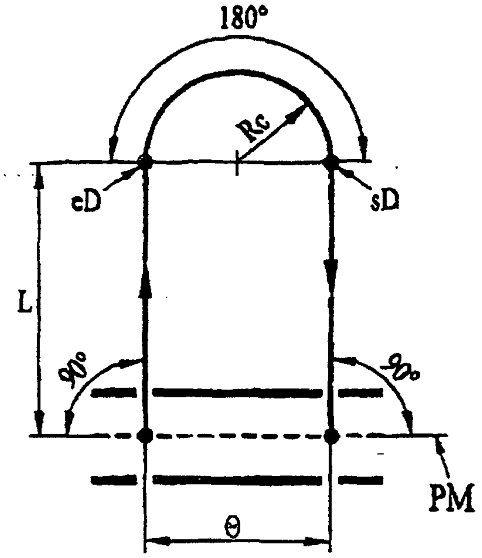

FIGURE 3 (a).

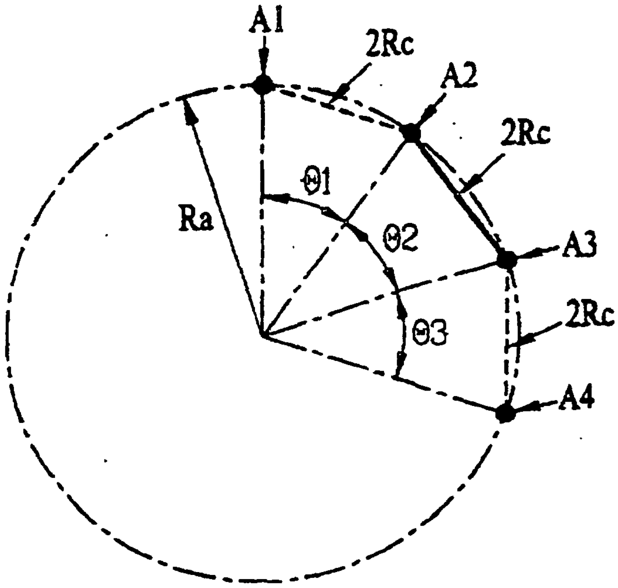

FIGURE 3 (b).