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(54) UNDULATOR FOR GENERATING ELECTROMAGNETIC RADIATION AND CORRESPONDING OPERATING METHOD

UNDULATOR ZUR ERZEUGUNG ELEKTROMAGNETISCHER STRAHLUNG UND ZUGEHÖRIGES
BETRIEBSVERFAHREN

ONDULATEUR DESTINÉ À GÉNÉRER UN RAYONNEMENT ÉLECTROMAGNÉTIQUE ET
PROCÉDÉ DE FONCTIONNEMENT CORRESPONDANT

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Description

FIELD OF THE INVENTION

[0001] The present invention concerns a flat and adjustable magnetic phase undulator configured to be used in the field of generation of electromagnetic radiation.

[0002] By undulator we mean the component of an apparatus for the generation of electromagnetic radiation, for example synchrotron light, which performs the function of conditioning the trajectory of the beam of charged particles used to produce said electromagnetic radiation.

[0003] The invention is applied by way of example in synchrotron rings, free electron lasers (FEL), cyclotrons, energy recovery linear accelerators (ERL) etc.

[0004] The invention also concerns an operating method of the undulator, which allows to assemble, adjust and optimize the magnetic configuration and to use the undulator.

BACKGROUND OF THE INVENTION

[0005] Known fixed gap and adjustable phase flat undulators can comprise two support beams, disposed one above the other, each of which has a magnetic array disposed and fixed on a surface of the support beam so that the two magnetic arrays are facing each other.

[0006] Each magnetic array comprises a multitude of permanent magnets, such as for example permanent magnets that include chemical elements of the rare earths group which have high residual induction, such as for example NdFeB and/or SmCo5 or suchlike.

[0007] It is known that, in order to keep the magnetic periodicity as precise as possible, the permanent magnets that make up the magnetic arrays are installed on specific single housing supports or holders, generally made of aluminum, on which it is possible to make workings used to position the magnets correctly.

[0008] It is also known that adjustable phase undulators are configured to vary the reciprocal longitudinal position (phase) of the two magnetic arrays so as to generate a magnetic field with desired characteristics.

[0009] In the state of the art, the support beams are located at a desired distance to form a gap between them, through which the beam of charged particles can pass. The distance is determined according to the characteristics of the undulator and the size of the vacuum chamber inside which the beam of charged particles passes during the operating phase.

[0010] During the operating phase, the motion of the charged particles transiting inside the vacuum chamber is conditioned by the magnetic field generated by the magnetic arrays, so as to obtain an oscillatory curvilinear trajectory, such as for example a sinusoidal trajectory.

[0011] It is known that, especially in the presence of attraction/repulsion magnetic forces generated between the magnetic arrays, known undulators have extremely rigid structures, such as for example box-shaped closed

structures.

[0012] These known undulators are very complex, structurally very bulky and also very heavy.

[0013] To be able to move and assemble the support beams of the magnetic arrays in the state of the art, lifting and assembly structures are used, they are configured to manage not only the overall weight of the mechanical parts but also the attraction force that is generated between the two support beams.

[0014] Known lifting and assembly structures are very bulky, and have a very high overall weight.

[0015] Due to their size and weight, the positioning of support beams of known magnetic arrays is very difficult, and does not allow to carry out, simply and quickly, the controls needed for a correct alignment both of the magnets on the support beams and also the support beams themselves.

[0016] Known undulators have other disadvantages connected to the presence of the large number of single housing supports, or holders, needed to have as precise a positioning as possible of the single magnets.

[0017] The large number of single housing supports entails a considerable increase in the production costs and an increase in the times needed to adjust the periodicity of the magnetic field.

[0018] Another disadvantage of known undulators is connected to the intrinsic characteristics of the closed box-like structure which does not give the possibility of making a measurement after the two support beams of the magnetic arrays have been assembled and positioned.

[0019] In fact, once assembled, the box-like structure does not allow access for probes to measure the magnetic field, and has other problems during the installation, in particular during the positioning on the vacuum chamber.

[0020] Furthermore, if the measurement of specific sectors of the undulator were to show the need for further magnetic optimizations, the box-like structure would need to be completely dismantled by using lifting systems, which entails a significant waste of time and increase in costs.

[0021] It is known to position, on each occasion, one or both the support beams so as to correct and optimize the trajectory of the charged particles in transit through the magnetic field generated by the magnetic arrays.

[0022] This technique, also known as tapering, provides the possibility of defining an angle, adjustable by a few degrees, between the support beams along the axis of advance of the beam of particles, so to vary the distance between them between entrance and exit of the particles from the undulator.

[0023] For example, document US 5.528.212 (US'212) describes an undulator in which the support beams can be rotated by spherical joints so as to vary the passage gap for the charged particles.

[0024] This rotation is not only limited to a few degrees, but also takes place around an axis orthogonal to the

longitudinal axis of the undulator.

[0025] The adjustment provided in US'212 in no way allows to make the magnetic arrays of the upper support beam accessible to the operator, and indeed US'212 neither deals with nor mentions this aspect.

[0026] Due to the closed box-like structure of the undulator described in US'212, it is therefore not possible for the operator, in any of the angled positions possibly obtainable, to easily perform operations of maintenance or measurement or any other type on the magnetic arrays of the upper support beam.

[0027] There is therefore a need to perfect the state of the art and make available a flat and adjustable magnetic phase undulator for generating synchrotron radiation, and the corresponding operating method, which overcome at least one of the disadvantages of the state of the art.

[0028] The purpose of the present invention is to obtain a flat fixed gap and adjustable phase undulator characterized in that it is easy to use during the steps of assembly and optimization of the magnetic field, with a limited overall weight and which does not need to use single housing supports, or holders, for positioning the magnets.

[0029] The inventive idea of the present invention allows to speed up the operations of assembly, measurement, control and optimization of the magnetic field, at the same time guaranteeing an accurate magnetic periodicity.

[0030] Another purpose of the present invention is to obtain an undulator that allows to perform these operations on both the support beams, also simultaneously, making their repositioning much quicker, even with only one operator, in the operating configuration without the aid of lifting means to contrast the high magnetic force of attraction.

[0031] The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

[0032] The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention .

[0033] In accordance with the above purposes, a flat adjustable phase undulator is provided, which is used in the generation of electromagnetic radiation, configured to be passed through by a beam of particles according to an axis of advance.

[0034] The undulator comprises a first lower support beam of one or more magnetic arrays, structurally connected to a second upper support beam of one or more magnetic arrays, by means of a hinging unit, to form a structure which can be opened like a book according to an axis parallel to the axis of advance of the beam of particles that passes through the undulator.

[0035] The hinging unit can comprise at least a rotation pin and a group of support brackets.

[0036] The support beams of the magnetic arrays may comprise one or more support elements mobile in a direction parallel to the longitudinal axis of the undulator, on which the magnetic arrays are positioned.

[0037] At least the upper support beam may have a movement assembly for each mobile support element that comprise at least a guide mating to at least a slider able to slide in a direction parallel to the longitudinal axis of the undulator.

[0038] The undulator is configured to assume in a univocal manner at least two stable configurations: a first open configuration suitable to allow the assembly of the magnetic arrays and to optimize the position thereof, and a second closed configuration characterizing the operating mode, that is, when the device is positioned on the vacuum chamber in which the charged particles of the beam of particles transit.

[0039] The magnetic arrays are mating with respect to each other to generate a magnetic field such as to condition the trajectory of the charged particles in the closed configuration.

[0040] In the closed configuration it is possible to create the conditions to carry out a measurement of the magnetic field, modifying the configuration of the box-like structure, so as to allow access to a measuring probe of the magnetic field along the longitudinal axis of the undulator.

[0041] The undulator is configured to allow the phase adjustment of the magnetic field so as to condition the trajectory of the charged particles and/or to also obtain a repulsive magnetic force between the magnets such as to reduce or cancel the weight of the upper support beam, also allowing to open manually the structure without the aid of lifting systems.

[0042] The phase adjustment of the magnetic field is obtained by moving at least one magnetic array of the upper support beam along an axis parallel to the longitudinal axis of the undulator.

[0043] In the open configuration the undulator is configured to allow to perform the assembly operations of the magnetic arrays and/or the operations to optimize the magnetic field generated by the magnetic arrays, keeping the orientation of the magnets substantially upward.

[0044] In the open configuration the undulator allows to operate on each support beam, at the same time avoiding having to realign the structure as happens in the state of the art.

[0045] According to the present invention, the method to use the undulator allows to pass from the open configuration to the closed configuration and vice versa by modifying the magnetic force from attractive to repulsive and vice versa.

[0046] The undulator comprises a plurality of multiple housing modules configured to allow the precise positioning on each of them of two or more pluralities of mag-

nets.

[0047] The plurality of multiple housing modules substitutes and improves the consolidated technique of single housing supports (holders), in which each support houses a single magnet, maintaining an equivalent or greater precision of the magnetic periodicity.

[0048] Using the magnets currently available, it is possible to dispose the magnets in such a way that they are misaligned with respect to each other on alternate axes along the longitudinal extension of the magnetic array, so as to be able to free on each magnet a surface of sizes such that it can be used as a support and/or reference element.

[0049] By exploiting the surfaces obtained by means of misalignment it is possible to obtain a precision of the magnetic periodicity equivalent or more stable and precise compared with the state of the art, using however a greater number of single housing supports (holders), with a consequent increase in production costs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] Aspects of the present invention will become apparent from the following description with reference to the attached drawings wherein:

- figs. 1 and 2 show two perspective views of an undulator for the generation of synchrotron radiation;
- figs. 3a and 3b show two lateral views in the two configurations, open and closed, of an undulator for the generation of synchrotron radiation ;
- fig. 4 shows a section in plane π in fig. 1 of an undulator;
- fig. 5 shows a detail of fig. 4 of an undulator;
- fig. 6 shows a detail of a multiple housing module for an undulator .

[0051] To facilitate comprehension, the same reference numbers have been used, where possible, to identify identical common elements in the drawings.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

[0052] With reference to the drawings, we shall now describe aspects of a flat adjustable phase undulator 10 and the corresponding operating method.

[0053] The undulator 10 can have a box-like shape and comprises at least two support beams: a first lower support beam 11a and a second upper support beam 11b, which can open book-like with respect to each other, each of which has on its surface one or more magnetic arrays 12.

[0054] The lower support beam 11a can be attached to the horizontal plane or to a base 27, for example by means of a plurality of adjustable supports 28 which also allow to adjust the distance thereof from the base 27.

[0055] Both the support beams 11a and 11b have a flat surface on which the multiple housing modules 14

are disposed and attached, with the magnets 15 to form the magnetic array 12.

[0056] Merely by way of example, in the drawings the lower support beam and the upper support beam are identified respectively by the reference numbers 11a and 11b.

[0057] The support beams 11a and 11b comprise one or more independently mobile support elements 13, with which one or more multiple housing modules 14 for the magnets 15 can be structurally associated.

[0058] In particular, the mobile support element or support elements 13 are provided only on the upper support beam 11b.

[0059] Accordingly, by moving the magnetic array or arrays 12 only on the upper support beam 11b, it is possible to obtain a more precise adjustment of the magnetic phase because the magnetic array or arrays 12 on the lower support beam 11a are stationary.

[0060] In the description, by magnetic array 12 we mean the array developed along the longitudinal axis of a support beam 11a-11b and which consists of a plurality of multiple housing modules 14 on which two or more magnets 15 are disposed, attached by lateral retaining elements 17.

[0061] In particular, the multiple housing modules 14 are configured to precisely house more than one magnet 15, with the advantage that each magnet 15, resting on a surface of the magnet 15 adjacent to it, has a stable and correct position.

[0062] The support elements 13 are disposed on a surface of each support beam 11a- and extend along part or all the length of the support beam 11a-11b with which they are associated.

[0063] The movement of the support elements 13, which for example can be mobile plates, is performed by a movement group 16.

[0064] If there is more than one support element 13 associated with each support beam 11a-11b, the movement group 16 comprises a movement unit 23 for each support element 13 (in the drawings, the movement unit 23 coincides with the movement unit 16 because there is only one support element 13 per beam). This allows to move independently also more than one support element 13 simultaneously.

[0065] If on one support beam 11a-11b there is only one support element 13 of a magnetic array 12, it is stationary, while the support element or support elements 13 associated with the other support beam 11a-11b are mobile independently by means of the movement group 16.

[0066] The movement unit 23 comprises a motor member 24 connected to a shaft 25, for example a recirculating ball screw, by means of which the rotational motion of the motor member 24 is transferred and converted into a translatory motion to and from a motion conversion member 29.

[0067] The motion conversion member 29 is structurally associated with a sliding support 30 in turn connected

to a support element 13; furthermore, the conversion member 29 can be an Archimedes screw for example, cooperating with the recirculating ball screw.

[0068] The sliding support 30 is structurally associated with a support element 13 by suitable association means 22, such as for example bayonet sockets, coupling screws or other similar type of connection.

[0069] The support element 13 is translated by the sliding support 30 along a guide 31, for example by means of a slider 32 structurally associated with the support element 13 to form a single body with it.

[0070] It is therefore possible to convert the rotational motion of the shaft 25 into a translatory motion of the support element 13.

[0071] The movement group 16 allows to displace at least one support element 13, and hence the magnetic arrays 12 connected to it, at least along the longitudinal axis of the upper support beam 11b.

[0072] The magnets 15, each having a defined magnetic orientation, are made for example of NdFeB and/or SmCo5.

[0073] If the support element 13 is a motorized sliding beam on which the magnetic array 12 is disposed, it can be connected directly to a motor member, not shown, itself able to translate the support element 13.

[0074] The support elements 13 are by way of example sliding plates or beams, such as for example a mobile slider, sliding by means of a movement group 16, on a guide structurally associated with the support beam 11a-11b in a direction parallel to the longitudinal axis of the support beam 11a-11b itself.

[0075] The multiple housing modules 14 are configured to contain the magnets 15, attaching their transverse position to a support plate 33 by means of the lateral retaining elements 17 (see fig. 6).

[0076] The lateral retaining elements 17 have a misaligned support surface such that the magnets 15 can be disposed on two alternate axes in the longitudinal direction of the undulator 10. This allows to obtain a precise and defined magnetic periodicity.

[0077] Even more than one magnetic array 12, not shown, can be associated with each support beam 11a-11b, and are each associated with their own specific movable support element 13.

[0078] The support beams 11a-11b are hinged along one side by means of a hinging unit 18 which comprises one or more connection elements 19, such as for example pins, hinges or other similar elements.

[0079] The hinging axis is disposed in a direction parallel to the longitudinal axis of the undulator and is located at the side of the axis of advance of the beam of particles along the undulator.

[0080] The upper support beam 11b is connected laterally to the structure and to the lower support beam 11a by means of a plurality of connection elements 19, each of which comprises a pin and a vertical bracket 18a and a horizontal bracket 18b.

[0081] The connection elements 19 are configured to

allow the rotation of one support beam 11b with respect to the other, around the axis of rotation of the connection elements 19 located laterally to the support beams 11a-11b.

[0082] The hinging unit 18 is structurally associated with the lower 11a and upper support beams and allows to have at least two configurations:

- a first open configuration, where the support beams 11a-11b are each positioned at an opposite side of the hinging unit 18 and allow easy access to the magnetic arrays 12;
- a second closed configuration, where each support beam 11a-11b has its own magnetic array or arrays 12 facing those of the other support beam 11a-11b, to form a working gap 20.

[0083] The first open configuration has easy access to the magnetic arrays 12 for the operations of assembly, measurement and optimization of the magnetic field on each of the support beams 11a and 11b.

[0084] The second closed configuration has the magnetic arrays 12 facing each other and also, to guarantee great mechanical precision and to prevent torsions on the structure, the two support beams 11a and are structurally attached by means of suitable association means 22, such as for example screws at the sides of one or more contrast elements 21.

[0085] The contrast elements 21 allow to maintain a stable closed configuration of the undulator 10, at the same time guaranteeing to return to the same position in the event of repeated openings/closings.

[0086] The undulator 10 provides a support element 26 located at the side of the lower support beam 11a and configured to support the upper support beam 11b in the open configuration.

[0087] In this way, by performing a suitable alignment, it is possible to measure simultaneously the lower support beam 11a and the upper support beam in the same measuring session, so as to be able to identify possible problems with the structure open, thus enabling the operator to perform an easy correction intervention.

[0088] Although not shown, the support element 26 is adjustable in height automatically, by lowering or raising the support plane for example by means of a motorized adjustment mechanism.

[0089] The undulator 10 is attached to at least one base 27 by means of adjustable supports 28 associated with it, which allow to adjust both the height and the planarity of the structure.

[0090] The possibility of assembling the magnets 15 without using single housing supports or holders, and opening manually the undulator 10 book-wise both in the assembly step and also in subsequent measurement and magnetic optimization steps, has the following advantages:

- lower production costs in that, especially for undu-

lators 10 having a short period and hence a large number of magnets 15, the need to have a large number of high precision mechanical components or holders is eliminated;

- extremely limited assembly times of the magnetic part, which in the case of serial production can decisively affect the production costs of the machine and its marketing costs;
- possibility of assembling the magnetic arrays 12 with great ease. In fact, the magnetic arrays 12 disposed on the support beams 11a and of the magnets 15, in the open configuration, are both easily accessible and facing upward. Furthermore, this allows to make measurements simultaneously on the two individual beams and the subsequent operations to optimize the magnetic field without needing dedicated equipment for a possible need to open and close the structure and without having to manage the magnetic interaction between the magnetic arrays 12 of the lower 11a and upper 11b beam.
- possibility of opening/closing the structure without using lifting means and/or special equipment. This operation is concluded with a careful management of the phase shift between the magnetic arrays 12 which compensates both the weight of the upper beam and also the force of magnetic attraction between the upper support beam and the lower support beam 11a. This possibility is extremely useful and advantageous, especially during installation on the vacuum chamber in the closed configuration.

[0091] The advantage of being able to open the undulator 10 book-wise until the surfaces of the support beams 11a-11b on which the magnetic arrays 12 are disposed are both facing upward allows to simplify and accelerate the operations of maintenance, intervention, control and adjustment of the magnetic periodicity.

[0092] In fact, the book-wise open configuration also allows several operators at the same time to perform the operations on each magnetic array 12 individually.

[0093] The open configuration not only allows to perform these operations by accessing the upper support beam without having to dismantle the whole apparatus, it also allows to operate with a greater level of safety than in the state of the art.

[0094] During the operating step, a beam of charged particles such as for example electrons transits in the gap 20 according to an axis of advance that develops along the longitudinal axis of the undulator. After the trajectory of the charged particles has been conditioned by the magnetic field generated by the magnetic arrays 12, the passage of the charged particles generates a synchrotron radiation.

[0095] It is possible to control the uniformity and periodicity of the magnetic field by means of suitable sensors, such as for example Hall probes or other type, both in the open configuration, to detect individually the magnetic fields generated by each magnetic array 12, and also

in the closed configuration, to detect the overall resultant magnetic field.

[0096] If the undulator 10 is in the closed configuration, it is possible to remove where necessary one or more contrast elements 21 so as to be able to access the gap 20 laterally and perform the magnetic measurement with the magnetic field sensor.

[0097] If it is desired to localize on which magnetic array 12 there is a possible lack of homogeneity or imperfection of the magnetic field, in the open configuration the undulator 10 allows to localize the zone where there is the imperfection and hence to intervene in order to correctly reposition the magnets 15.

[0098] The movement of the support elements 13, and hence of the magnetic arrays 12, can be performed both in the closed configuration and in the open configuration of the undulator 10.

[0099] The possibility of having one or more support elements 13 movable and motorized on both support beams 11a-11b allows to obtain the following advantages:

- it is possible to vary the magnetic phase of the magnetic field generated by the magnetic arrays 12, translating them by a desired length, also called specific phase shift, to which a correlated phase adjustment corresponds;
- by translating the magnetic arrays 12 it is possible to orientate the magnetic field so that it conditions the trajectory of the charged particles, causing them to follow a periodic curvilinear trajectory, such as for example a sinusoidal trajectory.

[0100] If the magnetic arrays 12 associated with the support elements 13 are translated until at least a specific phase shift is obtained which is greater than one quarter of the magnetic period between the magnetic arrays 12, the magnetic force from attractive becomes repulsive.

[0101] In this particular condition, by exploiting the repulsion between the support beams 11a-11b generated by the magnetic field, it is possible to open the undulator 10 more easily, without using lifting tools and/or several operators as happens in the state of the art.

[0102] After the magnetic arrays 12 have been spatially shifted and hence a repulsive magnetic force generated, the hinging unit 18 constrains the upper support beam to rotate in a direction parallel to the longitudinal axis of the undulator 10.

[0103] Thanks to the hinging unit 18 which associates the beams book-wise, if the undulator 10 is open and it is to be closed again, it returns exactly to the position assumed in the previous closure.

[0104] In the same way, starting from the condition in which the magnetic arrays 12 are spatially shifted so as to generate a repulsive magnetic force in the open configuration, they can again be shifted until the attractive magnetic force is obtained.

[0105] The operating method provides to exploit this

principle with which it is possible to change the direction and intensity of the magnetic force so as to facilitate the passage from the closed to the open configuration and vice versa.

[0106] Thanks to the hinging unit 18 which allows the undulator 10 to open book-wise, the passage between the different configurations takes place without using lifting tools.

[0107] Furthermore, again thanks to the hinging unit 18, it is possible to return more quickly and precisely compared with the state of the art into the same reciprocal position of the support beams 11a-11b.

[0108] It is clear that modifications and/or additions of parts may be made to the undulator and the corresponding operating method as described heretofore, without departing from the field and scope of the present invention.

Claims

1. Flat adjustable phase undulator, configured to be used in the generation of electromagnetic radiation, comprising a lower support beam (11a) and an upper support beam (11b) extending along a longitudinal axis, wherein the undulator comprises one or more magnetic arrays (12) provided on each of said support beams (11a, 11b) by means of one or more support elements (13) on which the one or more arrays (12) are disposed, each magnetic array (12) comprising a plurality of magnets (15), said support beams (11a, 11b) are hinged to each other along one side by means of a hinging unit (18) to form a structure which can be opened like a book, said hinging unit (18) being able to rotate said upper support beam (11b) around a direction parallel to the longitudinal axis of said undulator (10) into an open configuration, wherein said support beams (11a, 11b) are substantially parallel to a horizontal plane, on opposite sides of said hinging unit (18) so as to allow accessibility to said magnets (15), and into a closed configuration, wherein said support beams (11a, 11b) have said magnetic arrays (12) facing to form a defined gap (20).
2. Undulator as in claim 1, wherein said magnetic arrays (12) are obtained by attaching two or more of said magnets (15) on at least one multiple housing module (14).
3. Undulator as in claim 2, wherein at least one of said support elements (13) supporting at least one corresponding multiple housing module (14) is independently mobile by means of a respective movement group (16), in at least a direction parallel to the longitudinal axis of said undulator (10).
4. Undulator as in any of the claims from 1 to 3, wherein

it comprises at least an adjustable support element (26) configured to keep said magnetic arrays (12) of at least said upper support beam (11b) substantially parallel to the horizontal support plane.

5. Undulator as in any of the claims from 2 to 4, wherein said movement group (16) comprises a motor member (24) associated with at least a motion conversion member (29) that is structurally associated with at least a sliding support (30).
6. Undulator as in claim 5, wherein said sliding support (30) is structurally associated with said support element (13).
7. Undulator as in claim 5 or 6, wherein said conversion member (29) is configured to convert the rotatory motion of said shaft (25) into a translatory motion of said sliding support (30).
8. Operating method for an undulator as in any of the claims hereinbefore, wherein said undulator (10) passes from the closed configuration to the open configuration and vice versa, following an inversion of a force of a magnetic field from attraction to repulsion and vice versa, by means of a specific phase shift of said magnetic arrays (12) provided on said support beams (11a, 11b).

Patentansprüche

1. Planarer Undulator mit einstellbarer Phase, der zur Verwendung bei der Erzeugung elektromagnetischer Strahlung konfiguriert ist, umfassend eine untere Halteschiene (11a) und eine obere Halteschiene (11b), die sich entlang einer Längsachse erstrecken, wobei der Undulator ein oder mehrere Magnet-Arrays (12) umfasst, die auf jeder der Halteschienen (11a, 11b) durch ein oder mehrere Unterstützungselemente (13), auf denen das eine oder die mehreren Arrays (12) angeordnet sind, bereitgestellt werden, wobei jedes Magnet-Array (12) eine Vielzahl von Magneten (15) umfasst, und die Halteschienen (11a, 11b) entlang einer Seite durch eine Scharniereinheit (18) miteinander verbunden sind, um eine Struktur zu bilden, die wie ein Buch geöffnet werden kann, wobei die Scharniereinheit (18) imstande ist, die obere Halteschiene (11b) um eine Richtung parallel zu der Längsachse des Undulators (10) in eine offene Konfiguration, in der die Halteschienen (11a, 11b) im Wesentlichen parallel zu einer horizontalen Ebene auf entgegengesetzten Seiten der Scharniereinheit (18) vorliegen, so dass eine Zugänglichkeit zu den Magneten (15) ermöglicht wird, und in eine geschlossene Konfiguration, in der sich die Halteschienen (11a, 11b) mit den Magnet-Arrays (12) unter Bildung eines definierten Zwischenraums (20)

gegenüberliegen, zu drehen.

2. Undulator gemäß Anspruch 1, wobei die Magnet-Arrays (12) erhalten werden, indem zwei oder mehr der Magneten (15) auf wenigstens einem mehrgehäusigen Modul (14) befestigt werden. 5
3. Undulator gemäß Anspruch 2, wobei wenigstens eines der Unterstützungselemente (13), welches mindestens ein entsprechendes mehrgehäusiges Modul (14) trägt, durch eine jeweilige Bewegungsgruppe (16) in wenigstens einer Richtung parallel zu der Längsachse des Undulators (10) unabhängig beweglich ist. 10
4. Undulator gemäß irgendeinem der Ansprüche 1 bis 3, wobei er mindestens ein einstellbares Halteelement (26) umfasst, das so konfiguriert ist, dass die Magnet-Arrays (12) zumindest der oberen Halteschiene (11b) im Wesentlichen parallel zu der horizontalen Auflageebene gehalten werden. 15 20
5. Undulator gemäß irgendeinem der Ansprüche 2 bis 4, wobei die Bewegungsgruppe (16) ein Motorelement (24) umfasst, das mit mindestens einem Bewegungsumwandlungselement (29) verbunden ist, das strukturell mit mindestens einem Gleitträger (30) verbunden ist. 25
6. Undulator gemäß Anspruch 5, wobei der Gleitträger (30) strukturell mit dem Unterstützungselement (13) verbunden ist. 30
7. Undulator gemäß Anspruch 5 oder 6, wobei das Umwandlungselement (29) so konfiguriert ist, dass es die Drehbewegung der Welle (25) in eine Verschiebungsbewegung des Gleitträgers (30) umwandelt. 35
8. Betriebsverfahren für einen Undulator gemäß irgendeinem der vorhergehenden Ansprüche, wobei der Undulator (10) - einer Kraftumkehr eines Magnetfeldes von Anziehung und Abstoßung folgend und umgekehrt - durch eine spezifische Phasenverschiebung der auf den Halteschienen (11a, 11b) bereitgestellten Magnet-Arrays (12) von der geschlossenen Konfiguration in die offenen Konfiguration übergeht und umgekehrt. 40 45

Revendications

1. Ondulateur plat à phase réglable, configuré pour être utilisé dans la génération de rayonnement électromagnétique, comprenant une poutre de support inférieure (11a) et une poutre de support supérieure (11b) s'étendant selon un axe longitudinal, l'onduleur comprenant un ou plusieurs réseaux magnétiques (12) prévus sur chacune desdites poutres de 55

support (11a, 11b) au moyen d'un ou plusieurs éléments de support (13) sur lesquels lesdits un ou plusieurs réseaux (12) sont disposés, chaque réseau magnétique (12) comprenant une pluralité d'aimants (15), lesdites poutres de support (11a, 11b) sont articulées l'une à l'autre le long d'un côté au moyen d'une unité d'articulation (18) pour former une structure qui peut être ouverte comme un livre, ladite unité d'articulation (18) étant apte à faire tourner ladite poutre de support supérieure (11b) autour d'une direction parallèle à l'axe longitudinal dudit onduleur (10) dans une configuration ouverte, dans laquelle lesdites poutres de support (11a, 11b) sont sensiblement parallèles à un plan horizontal, sur des côtés opposés de ladite unité d'articulation (18) de manière à permettre l'accessibilité auxdits aimants (15), et dans une configuration fermée, dans laquelle lesdites poutres de support (11a, 11b) ont lesdits réseaux magnétiques (12) se faisant face de façon à former un espace défini (20).

2. Ondulateur selon la revendication 1, dans lequel lesdits réseaux magnétiques (12) sont obtenus en fixant deux ou plusieurs desdits aimants (15) sur au moins un module de logement multiple (14).
3. Ondulateur selon la revendication 2, dans lequel au moins un desdits éléments de support (13) supportant au moins un module de logement multiple (14) correspondant est mobile indépendamment au moyen d'un groupe de déplacement (16) respectif, dans au moins une direction parallèle à l'axe longitudinal dudit onduleur (10).
4. Ondulateur selon l'une quelconque des revendications 1 à 3, dans lequel il comprend au moins un élément de support réglable (26) configuré pour maintenir lesdits réseaux magnétiques (12) d'au moins ladite poutre de support supérieure (11b) sensiblement parallèles au plan horizontal de support.
5. Ondulateur selon l'une quelconque des revendications 2 à 4, dans lequel ledit groupe de déplacement (16) comprend un organe moteur (24) associé à au moins un organe de conversion de mouvement (29) qui est structurellement associé à au moins un support coulissant (30).
6. Ondulateur selon la revendication 5, dans lequel ledit support coulissant (30) est structurellement associé audit organe de support (13).
7. Ondulateur selon la revendication 5 ou la revendication 6, dans lequel ledit organe de conversion (29) est configuré pour convertir le mouvement de rotation dudit arbre (25) en un mouvement de translation dudit support coulissant (30).

8. Procédé de fonctionnement d'un onduleur selon l'une quelconque des revendications précédentes, dans lequel ledit onduleur (10) passe de la configuration fermée à la configuration ouverte et inversement, suite à une inversion d'une force d'un champ magnétique d'attraction en répulsion et inversement. 5
versa, au moyen d'un déphasage spécifique desdits réseaux magnétiques (12) prévus sur lesdites poutres de support (11a, 11b).

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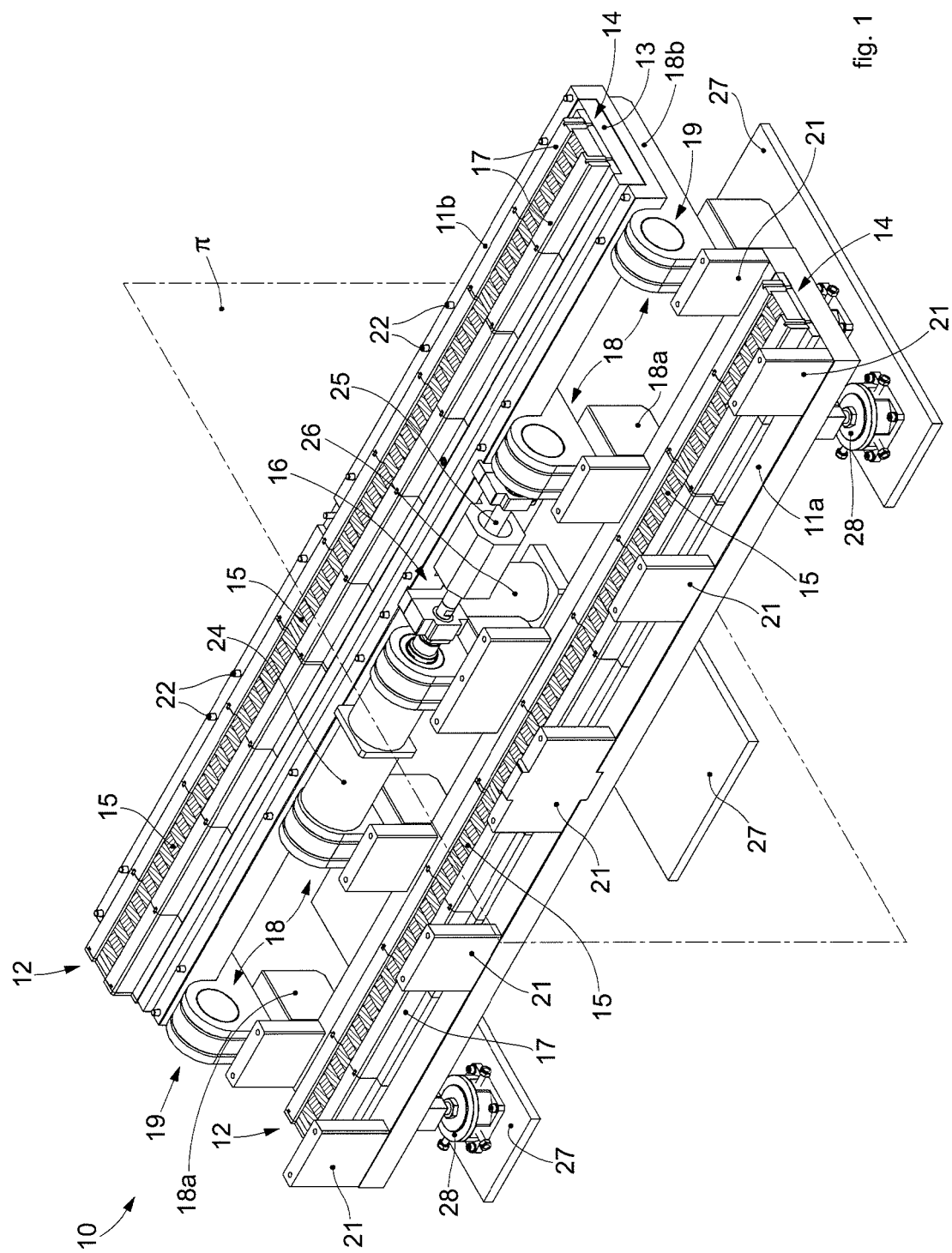
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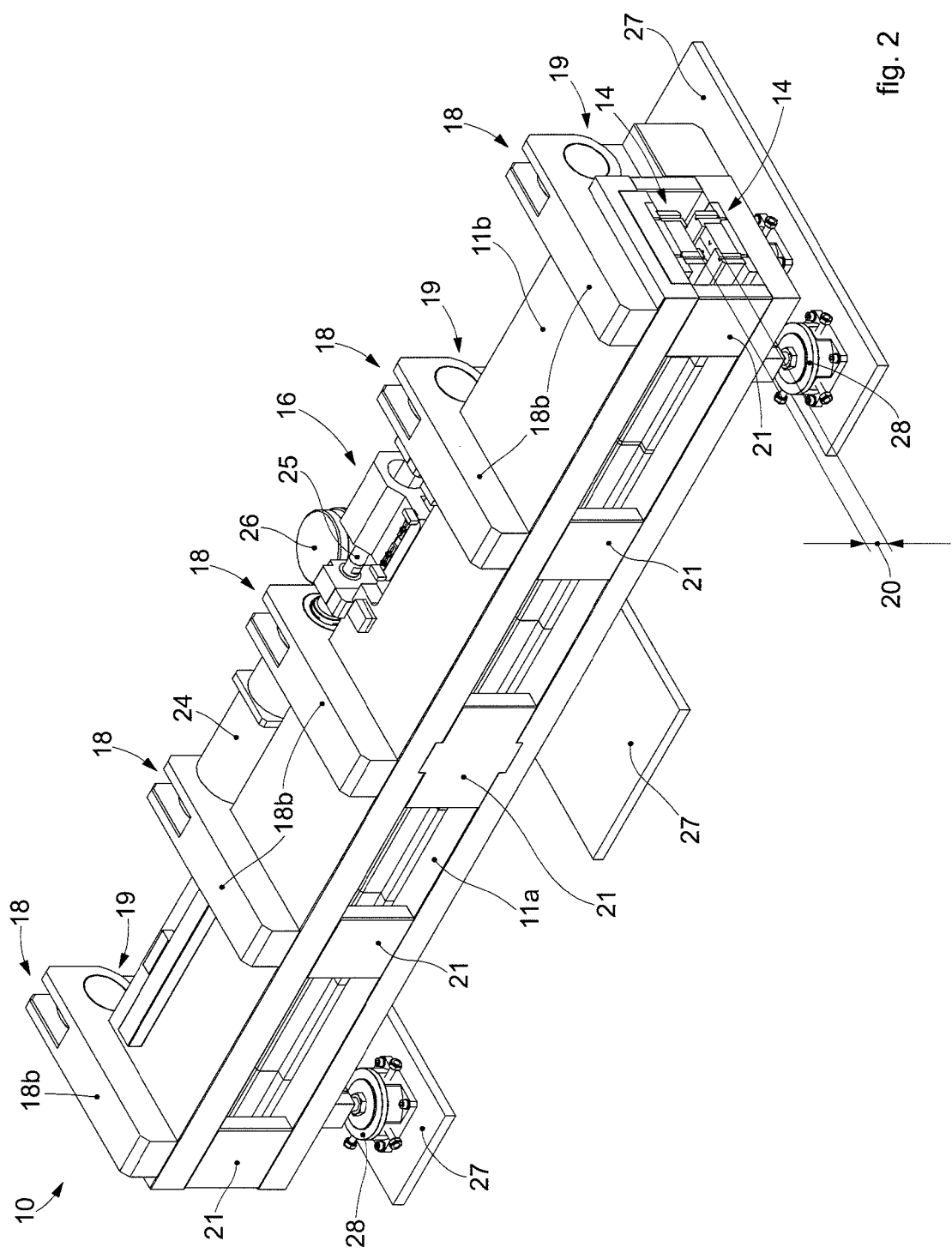
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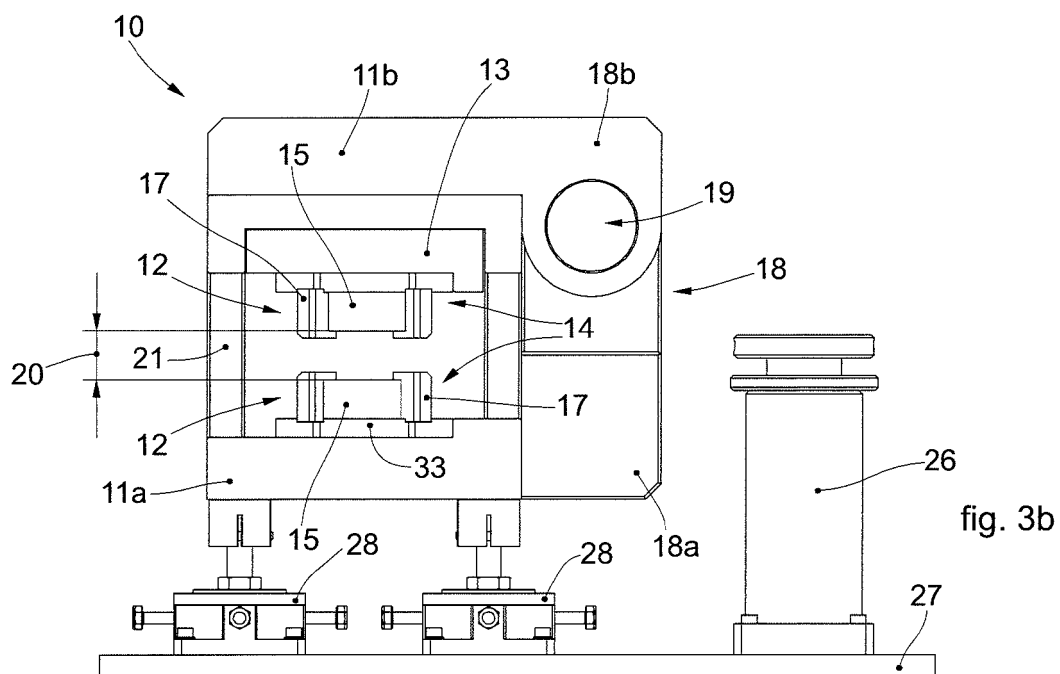
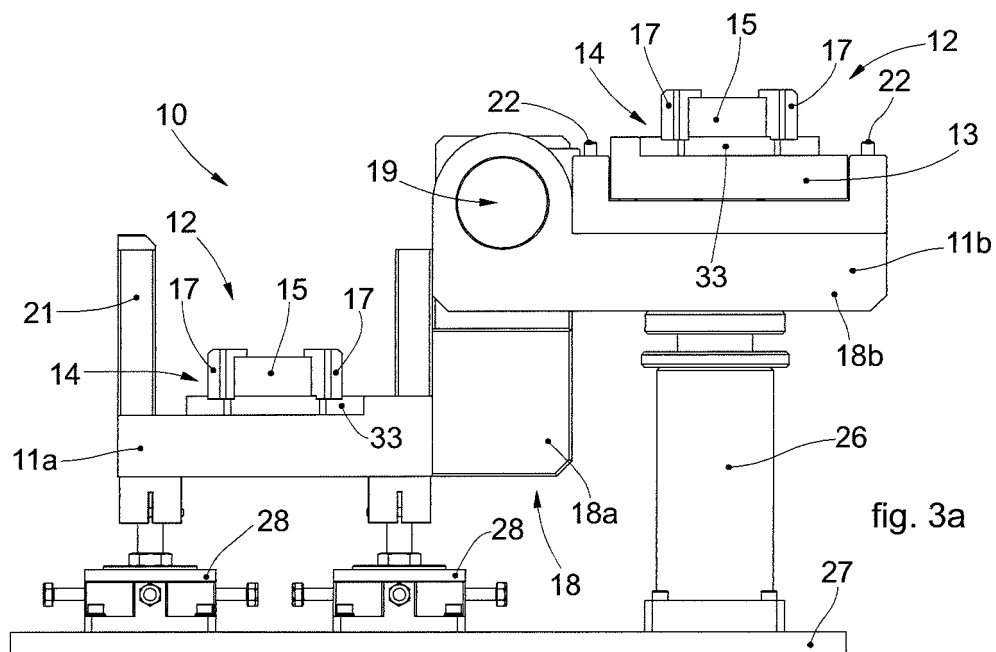
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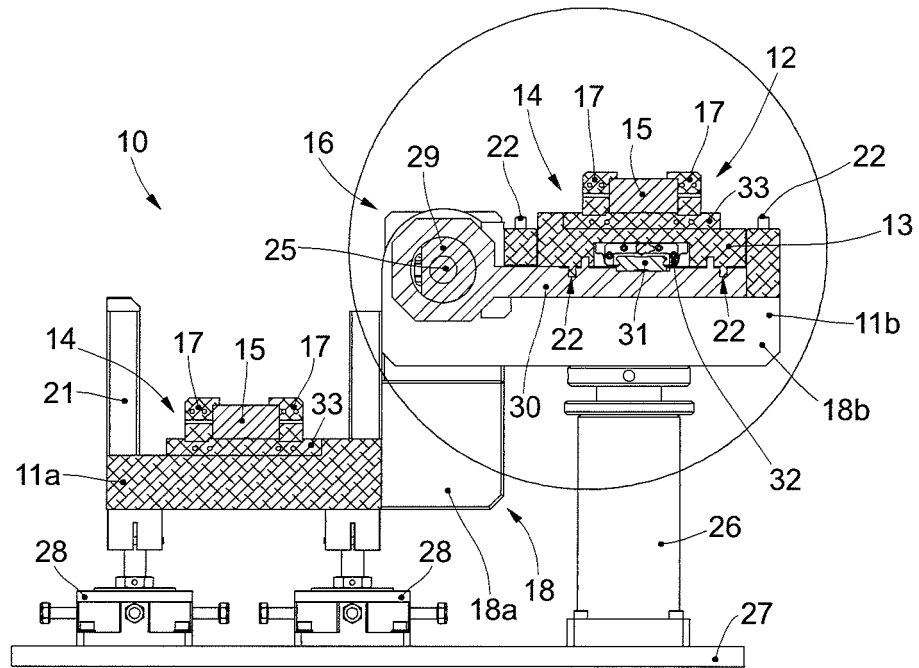


fig. 4

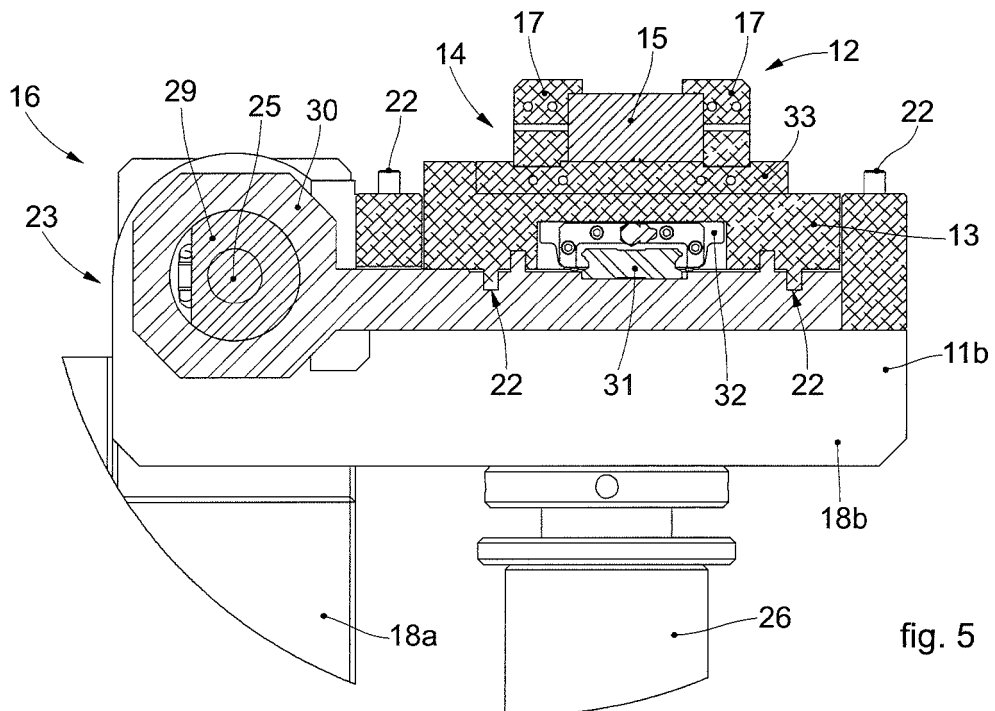
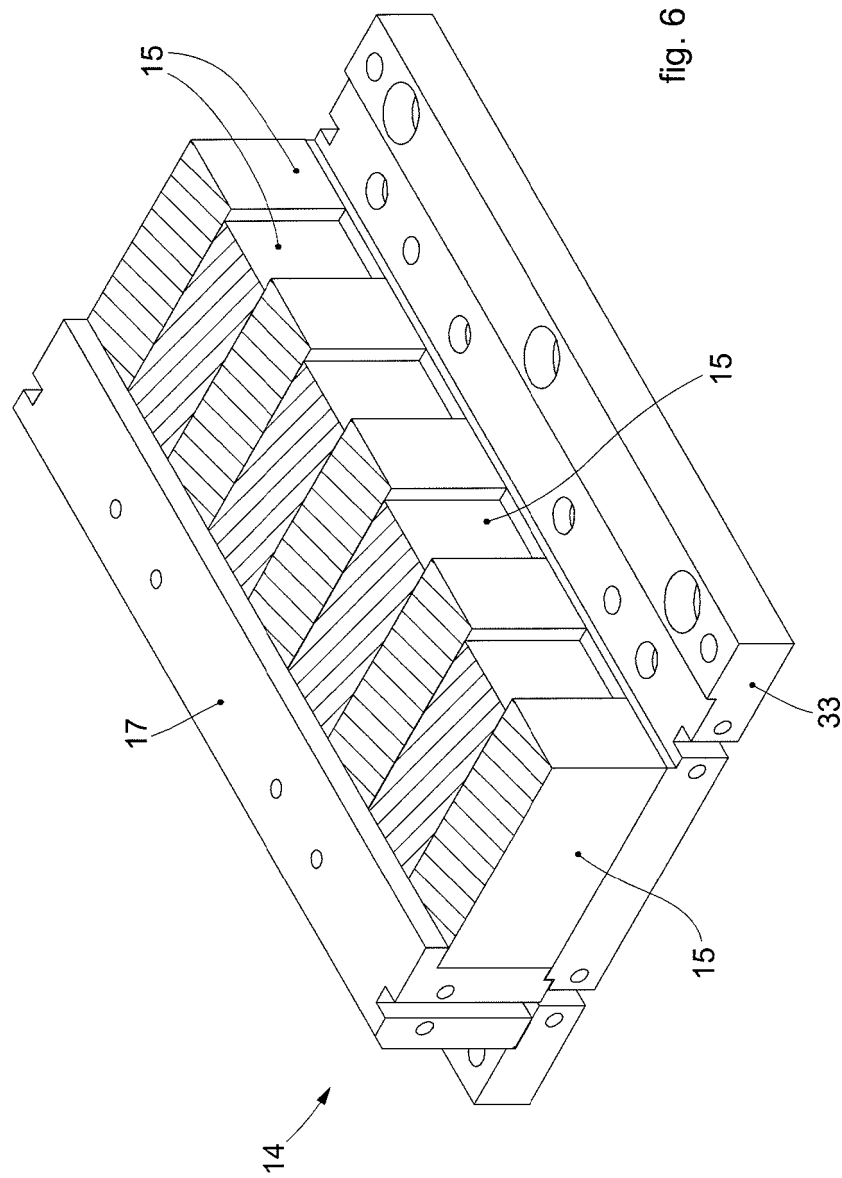


fig. 5



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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