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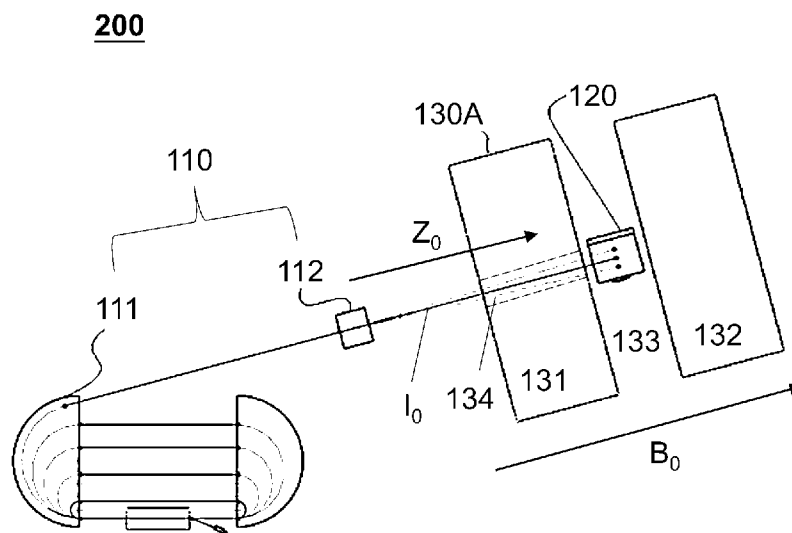


FIG. 2

(57) Abstract: A radiation treatment system, includes a radiation treatment device and a movable supporting device for supporting the target subject. The radiation treatment device may be configured to emit a radiation beam toward a target region of a target subject for radiation treatment. The movable supporting device may be configured to adjust a position of the target region relative to the radiation treatment device during the radiation treatment such that the target region is irradiated by the radiation beam from different directions.

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RADIATION TREATMENT SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of Chinese Patent Application No. 202310595658.0 filed on May 24, 2023, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to radiation treatment systems and methods, and in particular, to radiation treatment systems and methods using radiation beams.

BACKGROUND

[0003] With the development of electron acceleration techniques, radiation beams with different energy levels have been used in radiotherapy. For example, an electron beam with a low energy level (e.g., an energy lower than 50 megaelectron volts (MeV)) has a relatively insufficient penetrating ability and can be used to treat tumors near the body surface of the subject. An electron beam with a high energy level (e.g., an energy higher than 50 MeV) has a strong penetrability and a higher dose rate than the X-ray beam. Therefore, it is desirable to develop effective radiation treatment systems and methods using radiation beams, thereby providing an improved radiation beam radiotherapy technique.

SUMMARY

[0004] According to an aspect of the present disclosure, a radiation treatment system may be provided. The radiation treatment system may include a radiation treatment device and a movable supporting device for supporting the target subject. The radiation treatment device may be configured to emit a radiation beam toward a target region of a target subject for radiation treatment. The movable supporting device may be configured to adjust a position of the target region relative to the radiation treatment device during the radiation treatment such that the target region is irradiated by the radiation beam from different directions.

[0005] In some embodiments, an irradiation direction of the radiation beam may be substantially fixed.

[0006] In some embodiments, the movable supporting device may be rotatable such that the target region is able to be irradiated by the radiation beam from any angle.

[0007] In some embodiments, the radiation beam may be an electron beam, and an energy level of the electron beam may be greater than 50 megaelectron volts (MeV).

[0008] In some embodiments, the movable supporting device may be rotatable to change an orientation of the target region.

[0009] In some embodiments, the system may further include an imaging device configured to obtain one or more images of the target region during the radiation treatment.

[0010] In some embodiments, the imaging device may include a magnetic resonance imaging (MRI) scanner.

[0011] In some embodiments, an irradiation direction of the radiation beam may be substantially parallel to a main magnetic field of the MRI scanner.

[0012] In some embodiments, the MRI scanner may include a first main magnet, a second main magnet that is disposed opposite to the first main magnet, and an accommodation space between the first main magnet and the second main magnet for accommodating the target subject and the movable supporting device. At least one of the first main magnet or the second main magnet may include an open channel for the radiation beam to pass through to irradiate the target region.

[0013] In some embodiments, the imaging device may include a liftable computed tomography (CT) scanner or a liftable positron emission tomography (pet) scanner.

[0014] In some embodiments, a gantry of the liftable CT scanner or the liftable pet scanner may be lifted up when the radiation beam may be emitted by the radiation treatment device. The gantry of the liftable CT scanner or the liftable pet may be put down and surrounds the target subject for obtaining the image when the radiation beam may be stopped.

[0015] In some embodiments, the radiation treatment device may comprise a radiation beam emitter and a radiation beam adjustor. The radiation beam emitter may be configured to emit an initial radiation beam. The radiation beam adjustor may be configured to adjust the shape and/or direction of the initial radiation beam to generate the radiation beam that aligns to the target region.

[0016] In some embodiments, the radiation beam emitter may be located at a fixed location for emitting the initial radiation beam along a fixed direction.

[0017] In some embodiments, the radiation beam adjustor includes one of a scanning magnet that adjusts the initial radiation beam via a magnetic field, a microwave cavity that adjusts the initial radiation beam by applying a microwave field, or an electric field applying device that adjusts the

initial radiation beam by applying an electric field.

[0018] In some embodiments, the radiation beam emitter may include a radiation beam generator, a radiation beam accelerator, and one or more guiders. The radiation beam generator may be configured to generate the initial radiation beam. The radiation beam accelerator may be configured to accelerate the initial radiation beam. The radiation beam accelerator may include an accelerating element and a direction control element. The accelerating element may be configured to accelerate the initial radiation beam. The direction control element may be configured to control a moving direction of the initial radiation beam so that the initial radiation beam returns to the accelerating element at least one time. The one or more guiders may be configured to guide the initial radiation beam to enter into the radiation beam adjustor.

[0019] In some embodiments, the radiation beam accelerator may include a microtron.

[0020] In some embodiments, the microtron may be one of a betatron, a petal accelerator, and a race track linac.

[0021] In some embodiments, the initial radiation beam may return into the accelerating element multiple times along multiple annular trajectories. The one or more guiders may include multiple guiders disposed on different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels.

[0022] In some embodiments, the initial radiation beam may return into the accelerating element multiple times along multiple annular trajectories. The one or more guiders may include one or more movable guiders that are capable moved to different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels.

[0023] In some embodiments, the radiation treatment device may further include a beam regulator may be configured to split the initial radiation beam into multiple initial sub-beams transmitting along different directions. The radiation beam adjustor may include multiple adjusting components configured to adjust the initial sub-beams, respectively, to generate multiple sub-beams of the radiation beam. The multiple sub-beams may irradiate the target region from different directions.

[0024] In some embodiments, the beam regulator may include a beam splitting element and multiple constraint elements. The beam splitting element may be configured to split the initial radiation beam into the multiple initial sub-beams. The multiple constraint elements may be configured to constrain transmission directions of the multiple initial sub-beams so that each of the

multiple initial sub-beams enters into one of the multiple adjusting components.

[0025] In some embodiments, the system may further comprise a second radiation treatment device configured to emit a second radiation beam toward the target region of the target subject for the radiation treatment. The radiation beam and the second radiation beam may irradiate the target region from different directions.

[0026] In some embodiments, energy levels of the radiation beam and the second radiation beam may be determined based on the position of the target region relative to the radiation treatment device and the second radiation treatment device.

[0027] In some embodiments, the position of the target region relative to the radiation treatment device and the second radiation treatment device may be determined based on an image of the target region captured by an imaging device during the radiation treatment.

[0028] In some embodiments, the system may further comprise a converter and a collimator disposed between the radiation treatment device and the movable supporting device. The converter may be configured to convert the radiation beam into a third radiation beam. The collimator may be configured to adjust the third radiation beam to align to the target region.

[0029] According to another aspect of the present disclosure, a method for treating a target subject using a radiation treatment system may be provided. The radiation treatment system may include a radiation treatment device, a movable supporting device, an imaging device. The method may be implemented on a computing device having at least one processor and at least one storage device. The method may include causing a radiation treatment to be delivered a target subject according to a radiation treatment plan by performing the following operations. Specifically, the radiation treatment device may be caused to emit a radiation beam toward a target region of a target subject for radiation treatment according to the radiation treatment plan. The movable supporting device may be caused to adjust a position of the target region relative to the radiation treatment device according to the treatment plan such that the target region is irradiated by the radiation beam from different directions. The method may further include verifying the radiation treatment plan in real-time during the radiation treatment by performing the following operations. Specifically, the imaging device may be caused to collect one or more images of the target region during the radiation treatment. Whether the radiation treatment plan needs to be adjusted may be determined based on the one or more images.

[0030] According to yet another aspect of the present disclosure, a non-transitory computer readable medium may be provided. The non-transitory computer readable medium may comprise at least one set of instructions for treating a target subject using a radiation treatment system. The radiation treatment system may comprise a radiation treatment device, a movable supporting device, and an imaging device. When executed by one or more processors of a computing device, the at least one set of instructions causes the computing device to perform a method. The method may include causing a radiation treatment to be delivered a target subject according to a radiation treatment plan by performing the following operations. Specifically, the radiation treatment device may be caused to emit a radiation beam toward a target region of a target subject for radiation treatment according to the radiation treatment plan. The movable supporting device may be caused to adjust a position of the target region relative to the radiation treatment device according to the treatment plan such that the target region is irradiated by the radiation beam from different directions. The method may further include verifying the radiation treatment plan in real-time during the radiation treatment by performing the following operations. Specifically, the imaging device may be caused to collect one or more images of the target region during the radiation treatment. Whether the radiation treatment plan needs to be adjusted may be determined based on the one or more images.

[0031] Additional features will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following and the accompanying drawings or may be learned by production or operation of the examples. The features of the present disclosure may be realized and attained by practice or use of various aspects of the methodologies, instrumentalities, and combinations set forth in the detailed examples discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The present disclosure is further described in terms of exemplary embodiments. These exemplary embodiments are described in detail with reference to the drawings. These embodiments are non-limiting exemplary embodiments, in which like reference numerals represent similar structures throughout the several views of the drawings, and wherein:

[0033] FIG. 1 is a block diagram illustrating exemplary radiation treatment system according to some embodiments of the present disclosure;

[0034] FIG. 2 is a schematic diagram illustrating an exemplary radiation treatment system according to some embodiments of the present disclosure;

[0035] FIG. 3A is a schematic diagram illustrating an exemplary radiation beam emitter according to some embodiments of the present disclosure;

[0036] FIG. 3B is a schematic diagram illustrating another exemplary radiation beam emitter according to some embodiments of the present disclosure;

[0037] FIG. 4 is a schematic diagram illustrating another exemplary radiation treatment system according to some embodiments of the present disclosure;

[0038] FIG. 5 is a schematic diagram illustrating an exemplary radiation treatment system according to some embodiments of the present disclosure;

[0039] FIG. 6 is a schematic diagram illustrating an exemplary radiation treatment system according to some embodiments of the present disclosure;

[0040] FIG. 7 is a schematic diagram illustrating an exemplary radiation treatment system according to some embodiments of the present disclosure; and

[0041] FIG. 8 is a flowchart illustrating an exemplary process for treating a target subject using a radiation treatment system according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

[0042] In the following detailed description, numerous specific details are set forth by way of examples in order to provide a thorough understanding of the relevant disclosure. However, it should be apparent to those skilled in the art that the present disclosure may be practiced without such details. In other instances, well-known methods, procedures, systems, components, and/or circuitry have been described at a relatively high level, without detail, in order to avoid unnecessarily obscuring aspects of the present disclosure. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present disclosure. Thus, the present disclosure is not limited to the embodiments shown, but to be accorded the widest scope consistent with the claims.

[0043] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates

otherwise. It will be further understood that the terms “comprise,” “comprises,” and/or “comprising,” “include,” “includes,” and/or “including,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0044] It will be understood that the term “system,” “engine,” “unit,” “module,” and/or “block” used herein are one method to distinguish different components, elements, parts, sections or assembly of different levels in ascending order. However, the terms may be displaced by another expression if they achieve the same purpose.

[0045] It will be understood that when a unit, engine, module, or block is referred to as being “on,” “connected to,” or “coupled to,” another unit, engine, module, or block, it may be directly on, connected or coupled to, or communicate with the other unit, engine, module, or block, or an intervening unit, engine, module, or block may be present, unless the context clearly indicates otherwise. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0046] It will be understood that, although the terms “first,” “second,” “third,” “fourth,” etc., may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of example embodiments of the present invention.

[0047] Spatial and functional relationships between elements (for example, between crystal elements) are described using various terms, including “connected,” “engaged,” “interfaced,” and “coupled.” Unless explicitly described as being “direct,” when a relationship between first and second elements is described in the present disclosure, that relationship includes a direct relationship where no other intervening elements are present between the first and second elements, and also an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. In contrast, when an element is referred to as being “directly” connected, engaged, interfaced, or coupled to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between,” versus “directly between,”

"adjacent," versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0048] An anatomical structure shown in an image of a subject (e.g., a patient) may correspond to an actual anatomical structure existing in or on the subject's body. The term "object" and "subject" in the present disclosure are used interchangeably to refer to a biological object (e.g., a patient, an animal) or a non-biological object (e.g., a phantom). In some embodiments, the object may include a specific part, organ, and/or tissue of the object. For example, the object may include the head, the bladder, the brain, the neck, the torso, a shoulder, an arm, the thorax, the heart, the stomach, a blood vessel, soft tissue, a knee, a foot, or the like, or any combination thereof, of a patient.

[0049] These and other features, and characteristics of the present disclosure, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, may become more apparent upon consideration of the following description with reference to the accompanying drawings, all of which form a part of this disclosure. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended to limit the scope of the present disclosure. It is understood that the drawings are not to scale.

[0050] Conventionally, a radiation treatment system based on a radiation beam (e.g., an electron beam) usually uses a radiation beam emitter to emit the radiation beam, and the radiation beam emitter is mounted on a rotatable gantry that rotates around a rotation center. The radiation beam emitter rotates with the rotatable gantry so that a subject is irradiated by the radiation beam from multiple directions. However, the rotatable gantry is usually bulky and has a high cost (e.g., a high manufacturing cost, a maintenance cost, etc.), and the radiation treatment system has a low practicability.

[0051] An aspect of the present disclosure provides a radiation treatment system. The radiation treatment system may include a radiation treatment device and a movable supporting device. The radiation treatment device may be configured to emit a radiation beam toward a target region of a target subject for radiation treatment. The movable supporting device may be used for supporting the target subject. The movable supporting device may be configured to adjust a position of the target region relative to the radiation treatment device during the radiation treatment such that the target region is irradiated by the radiation beam from different directions. For example, a radiation

beam emitter of the radiation treatment device is configured to emit an initial radiation beam along a fixed direction, which may be adjusted by a radiation beam adjustor to form the radiation beam.

The movable supporting device is a rotatable device that is separated from the radiation beam emitter of the radiation treatment device, and the target subject can set or stand on the rotatable device. When the rotatable device rotates, the target subject can be irradiated by the radiation beam from different directions.

[0052] Compared with the conventional radiation treatment system, the system of the present disclosure may achieve radiation treatment from different directions using the movable supporting device instead of the rotational gantry, which have a smaller size, a lower cost (e.g., a high manufacturing cost, a maintenance cost, etc.), thereby having a high practicability.

[0053] FIG. 1 is a block diagram illustrating exemplary radiation treatment system 100 according to some embodiments of the present disclosure.

[0054] In some embodiments, as illustrated in FIG. 1, the radiation treatment system 100 may include a radiation treatment device 110, a movable supporting device 120, an imaging device 130, and a processing device 140. The components of the radiation treatment system 100 may be communicatively connected in various manners.

[0055] The radiation treatment device 110 may be configured to emit one or more radiation beams to a target region of a target subject for radiation treatment. The target subject may include a biological subject (e.g., a human being, an animal, a plant, or a portion thereof) and/or a non-biological subject (e.g., a phantom). A target region refers to a certain anatomical structure that needs to be tracked or monitored during the radiotherapy treatment. For example, the target region may be a tumor, an organ with a tumor, a tissue with a tumor, or any combination thereof, that needs to be treated by radiation. The radiation beam(s) may include an electron beam, a photon beam, a hadron (e.g., proton, ion) beam, X rays, a neutron beam, α rays, β rays, γ rays, or other types of radiation beam.

[0056] The movable supporting device 120 may be used for supporting the target subject. In some embodiments, the movable supporting device 120 may be configured to adjust a position of the target region relative to the radiation treatment device 110 during the radiation treatment such that the target region is irradiated by the radiation beam from different directions.

[0057] In some embodiments, the radiation treatment device 110 may include a radiation beam

emitter configured to emit an initial radiation beam, and the initial radiation beam may be processed (e.g., split, shaped, deflected) to generate the radiation beam for irradiating the target region. In some embodiments, an irradiation direction of the radiation beam is substantially fixed. The irradiation direction of the radiation beam refers to a propagation direction of the radiation beam after the radiation beam leaves the radiation treatment device 110. As shown in FIG. 2, the irradiation direction of the radiation beam I_0 is a direction Z_0 . The irradiation direction of the radiation beam is substantially fixed may indicate that differences between irradiation directions of the radiation beams for different radiation treatments are below a threshold, e.g., 1%, 5%.

[0058] In some embodiments, the radiation beam emitter of the radiation treatment device 110 may be located at a fixed location for emitting the initial radiation beam along a fixed direction. The fixed direction refers to a moving direction of the initial radiation beam when the initial radiation beam leaves the radiation beam emitter (e.g., a direction pointing from the radiation beam emitter 111 towards the radiation beam adjustor 112 shown in FIG. 2, or a direction pointing from the radiation beam emitter 111 towards the beam regulator 1131 shown in FIG. 4). In some embodiments, the radiation beam emitter may be positioned to the fixed location before the radiation treatment via a supporting component (e.g., a supporting frame). Optionally, the supporting component is movable so that the radiation beam emitter can be positioned conveniently to different positions for performing different treatment.

[0059] As described elsewhere in the present disclosure, the radiation beam emitter of the conventional radiation treatment system is mounted on a rotatable gantry that rotates around a rotation center and rotates with the rotatable gantry. A subject to be treated and a supporting device for supporting the subject needs to be positioned within a rotation aperture formed by the rotation of the rotatable gantry to receive the radiation beam. Compared with the conventional radiation treatment system, since the radiation beam emitter of the radiation treatment device 110 is not mounted on a rotatable gantry, the movable supporting device 120 does not need to be positioned within a rotation aperture formed by the rotation of the rotatable gantry, the installation position of the movable supporting device 120 may be relatively flexible. Moreover, the installation positions of the radiation beam emitter can also be adjusted flexibly. In this way, the relative position between the radiation beam emitter and the movable supporting device 120 can be adjusted flexibly according to actual needs.

[0060] The imaging device 130 may generate or provide image data related to the target subject via scanning the target subject. For example, the imaging device 130 may obtain one or more images of the target region before, during, or after the radiation treatment. Specifically, the imaging device 130 may obtain images during the radiation treatment for achieving image guided radiation therapy (IGRT).

[0061] In some embodiments, the imaging device 130 may include a single modality imaging device and/or a multi-modality imaging device. The single modality imaging device may include, for example, an ultrasound imaging device, an X-ray imaging device, an computed tomography (CT) device, a magnetic resonance imaging (MRI) device, an ultrasonography device, a positron emission tomography (PET) device, an optical coherence tomography (OCT) imaging device, an ultrasound (US) imaging device, an intravascular ultrasound (IVUS) imaging device, a near-infrared spectroscopy (NIRS) imaging device, a far-infrared (FIR) imaging device, or the like, or any combination thereof. The multi-modality imaging device may include, for example, an X-ray imaging-magnetic resonance imaging (X-ray-MRI) device, a positron emission tomography-X-ray imaging (PET-X-ray) device, a single-photon emission computed tomography-magnetic resonance imaging (SPECT-MRI) device, a positron emission tomography-computed tomography (PET-CT) device, a C-arm device, a digital subtraction angiography-magnetic resonance imaging (DSA-MRI) device, etc.

[0062] In some embodiments, the imaging device 130 may be an MRI scanner located at a fixed location, and include an accommodation space for accommodating the target subject and the movable supporting device 120. The movable supporting device 120 may be located a position in the accommodation space. In some embodiments, the imaging device 130 may be a liftable computed tomography (CT) scanner or a liftable positron emission tomography (PET) scanner. The movable supporting device 120 may be located within an imaging channel of the liftable CT scanner or the liftable PET scanner.

[0063] The processing device 140 may process data obtained from the radiation treatment device 110, the imaging device 130, or other components of the radiation treatment system 100. In some embodiments, the processing device 140 may execute methods of the present disclosure. For example, the processing device 140 may cause radiation treatment to be delivered to a target subject according to a radiation treatment plan. Specifically, the processing device 140 may cause

the radiation treatment device 110 to emit a radiation beam toward a target region of the target subject for radiation treatment according to the radiation treatment plan. The processing device 140 may cause the movable supporting device 120 to adjust a position of the target region relative to the radiation treatment device 110 according to the treatment plan such that the target region is irradiated by the radiation beam from different directions. Further, the processing device 140 may verify the radiation treatment plan in real-time during the radiation treatment based on one or more images collected by the imaging device 130 during the radiation treatment.

[0064] In some embodiments, the processing device 140 may be a single server or a server group. The server group may be centralized or distributed. In some embodiments, the processing device 140 may be local or remote. Merely for illustration, only one processing device 140 is described in the medical system 100. However, it should be noted that the medical system 100 in the present disclosure may also include multiple processing devices. Thus, operations and/or method steps that are performed by one processing device 140 as described in the present disclosure may also be jointly or separately performed by the multiple processing devices. For example, if in the present disclosure the processing device 140 of the medical system 100 executes both process A and process B, it should be understood that the process A and the process B may also be performed by two or more different processing devices jointly or separately in the medical system 100 (e.g., a first processing device executes process A and a second processing device executes process B, or the first and second processing devices jointly execute processes A and B).

[0065] It should be noted that the above description of the radiation treatment system 100 is merely provided for the purposes of illustration, and not intended to limit the scope of the present disclosure. For persons having ordinary skills in the art, multiple variations and modifications may be made under the teachings of the present disclosure. For example, the radiation treatment system 100 may include one or more additional components and/or one or more components of the radiation treatment system 100 described above may be omitted. For example, the radiation treatment system 100 may include a network configured to facilitate exchange of information and/or data. In some embodiments, one or more components (e.g., the radiation treatment device 110, the movable supporting device 120, the imaging device 130, or the processing device 140) of the radiation treatment system 100 may send information and/or data to other component(s) of the radiation treatment system 100 via the network. As another example, the radiation treatment

system 100 may include a storage device configured to store data, instructions, and/or any other information. Additionally or alternatively, two or more components of the radiation treatment system 100 may be integrated into a single component. For example, the processing device 140 may be integrated into the radiation treatment device. A component of the radiation treatment system 100 may be implemented on two or more sub-components.

[0066] FIG. 2 is a schematic diagram illustrating an exemplary radiation treatment system 200 according to some embodiments of the present disclosure. In some embodiments, the radiation treatment system 200 may be an exemplary embodiment of the radiation treatment system 100 as described in connection with FIG. 1.

[0067] As shown in FIG. 2, the radiation treatment system 200 may include the radiation treatment device 110, the movable supporting device 120, an MRI scanner 130A, and the processing device 140 (not shown).

[0068] The radiation treatment device 110 may be configured to emit a radiation beam toward a target region of a target subject for radiation treatment.

[0069] The radiation beam may have a certain energy level. In some embodiments, the radiation beam may have a high energy level. For example, the radiation beam is an electron beam, and an energy level of the electron beam may be greater than 50 megaelectron volts (MeV). Merely by way of example, the electron beam may have a high energy level in a range from 50 MeV to 300 MeV or 100 MeV to 300 MeV. In some embodiments, the radiation beam may have a low energy level. For example, the radiation beam is an electron beam with an energy lower than 50 MeV. In some embodiments, a radiation beam with a high energy level may be referred to as a high-energy radiation beam, and a radiation beam with a low energy level may be referred to as a low-energy radiation beam. The high-energy radiation beam may have better penetrability than the low energy radiation beam. The low energy radiation beam may be more suitable for treating a target on or near the body surface of the subject, while the high-energy radiation beam may be more suitable for treating a target inside the target subject.

[0070] The movable supporting device 120 may be used for supporting the target subject. The target subject may be supported by the movable supporting device 120 in various ways and need to maintain a specific posture during the radiation treatment. For example, the target subject may stand, lie, or sit on the movable supporting device 120. In some embodiments, the movable

supporting device 120 may include a component (e.g., a backrest) for assisting the target subject to maintain a specific posture. In some embodiments, the movable supporting device 120 may include a chair, a table, a platform, or the like.

[0071] In some embodiments, the movable supporting device 120 may be configured to adjust a position of the target region relative to the radiation treatment device 110 during the radiation treatment such that the target region is irradiated by the radiation beam from different directions. In some embodiments, the movable supporting device 120 has multiple degrees of freedom of motion (6 degrees of freedom of motion) such that the position of the target region relative to the radiation treatment device 110 can be adjusted to a suitable position. In some embodiments, the movable supporting device 120 may be rotatable such that the target region is able to be irradiated by the radiation beam from any angle. Specifically, the movable supporting device 120 may be rotatable to change an orientation of the target region. For example, similar to aircraft movement, the movable supporting device 120 may perform a pitch operation, a roll operation, a yaw operation, etc., to rotate to a appropriate position. Merely by way of example, when the target object is sitting on the movable supporting device 120 facing the radiation treatment device 110, the movable supporting device 120 may rotate so that the target object faces away from the radiation treatment device 110. In some embodiments, the movable supporting device 120 may be translatable such that different portions of the target region are able to be irradiated by the radiation beam. As another example, the movable supporting device 120 may move along different directions to change a position of the target region. For example, the movable supporting device 120 may go up or down. As another example, the movable supporting device 120 may move left or right.

[0072] In some embodiments, the radiation treatment device 110 may include a radiation beam emitter 111 and a radiation beam adjustor 112. The radiation beam adjustor 112 may be located between the radiation beam emitter 111 and the movable supporting device 120.

[0073] The radiation beam emitter 111 may be configured to emit an initial radiation beam. In some embodiments, the radiation beam emitter 111 may include a radiation beam generator, a radiation beam accelerator, and one or more guiders. The radiation beam emitter may be configured to generate the initial radiation beam. The radiation beam accelerator may be configured to accelerate the initial radiation beam. The one or more guiders may be configured to guide the accelerated initial radiation beam to enter into the radiation beam adjustor 112. More

descriptions regarding the radiation beam emitter 111 may be found elsewhere in the present disclosure (e.g., FIGs. 3A and 3B, and the descriptions thereof).

[0074] The radiation beam adjustor 112 may be configured to adjust the initial radiation beam to generate the radiation beam that aligns to the target region. For example, if the radiation beam covers at least a portion of the target region, it is considered that the radiation beam aligns to the target region.

[0075] In some embodiments, the initial radiation beam generated by the radiation beam emitter 111 may be defocused, focused, shaped, deflected, etc., by the radiation beam adjustor 112 to generate the radiation beam and enter the target subject. In some embodiments, the radiation beam adjustor 112 may adjust the initial radiation beam to achieve a desired depth dose distribution in the target subject. As used herein, a depth refers to a distance with respect to the body surface of the target subject measured in a direction parallel to a radiation beam that enters the target subject (e.g., a central axis of the radiation beam). A depth dose distribution refers to a distribution of radiation dose at different depths. A desired depth dose distribution may be achieved if a larger portion of the total radiation dose is deposited in the target region than in a non-target region (i.e., a region of the target subject other than the target region).

[0076] In some embodiments, the radiation beam adjustor 112 may include a deflection element and/or a beam profile modulator. The deflection element may be configured to adjust a moving trajectory (e.g., the moving direction) of the initial radiation beam, that is, the moving trajectory of the initial radiation beam may be altered by the deflection element when it passes through the deflection element. In some embodiments, the deflection element may include a scanning magnet that adjusts the initial radiation beam via a magnetic field, a microwave cavity that adjusts the initial radiation beam by applying a microwave field, an electric field applying device that adjusts the initial radiation beam by applying an electric field, or the like. The beam profile modulator may be configured to shape the initial radiation beam. Merely by way of example, the beam profile modulator may include one or more beam-limiting elements, such as a multi-leaf collimator, a blocker, that may block a specific portion of the initial radiation beam.

[0077] In some embodiments, the radiation beam emitter 111 may be separated from the radiation beam adjustor 112 as shown in FIG. 2. It should be noted that the positions of the radiation beam emitter 111 and the radiation beam adjustor 112 can be adjusted according to an actual need. For

example, the radiation beam adjustor 112 may be mounted near an outlet (i.e., one or more exits of the one or more guiders) of the radiation beam emitter 111 for emitting the radiation beam.

[0078] The MRI scanner 130A may be an exemplary imaging device 130 as described in connection with FIG. 1, and a top view of the MRI scanner 130A is shown in FIG. 2. The MRI scanner 130A may be configured to acquire MRI images of the target region, which may be used to guide the radiation treatment in real-time or substantially real-time during the radiation treatment to compensate for motion (e.g., physiological motion, rigid body motion) of the target subject during the radiation treatment. An irradiation direction of the radiation beam may be parallel to (or substantially parallel to) a main magnetic field of the MRI scanner 130A to reduce or avoid the effect of the main magnetic field on the movement of the radiation beam. In some embodiments, a direction from the head to the feet of the target subject may be perpendicular to (or substantially perpendicular to) the main magnetic field B_0 of the MRI scanner 130A. As shown in FIG. 2, the irradiation direction Z_0 of the radiation beam I_0 may be parallel to (or substantially parallel to) the main magnetic field B_0 of the MRI scanner 130A. The target subject may set or stand on the movable supporting device 120 and the direction from the head to the feet of the target subject may be perpendicular to (or substantially perpendicular to) the main magnetic field B_0 of the MRI scanner 130A.

[0079] The radiation beam may include multiple beamlets, and the irradiation direction of the radiation beam refers to an irradiation direction of the beamlet that passes through the center of the radiation beam. In some embodiments, the multiple beamlets of the radiation beam are substantially parallel. Merely by way of example, multiple beamlets are substantially parallel may indicate that differences between irradiation directions of the multiple beamlets are below a threshold, e.g., 1° , 2° .

[0080] As shown in FIG. 2, the MRI scanner 130A may include a first main magnet 131, a second main magnet 132 that is disposed opposite to the first main magnet 131, and an accommodation space 133 between the first main magnet 131 and the second main magnet 132 for accommodating the target subject and the movable supporting device 120. At least one of the first main magnet 131 or the second main magnet 132 may include an open channel 134 for the radiation beam to pass through to irradiate the target region. For example, for the MRI scanner 130A as shown in FIG. 2, one of the first main magnet 131 and the second main magnet 132 that is close to

the radiation treatment device 110 (i.e., the first main magnet 131) may include an open channel 134. As another example, for the MRI scanner as shown in FIG. 4, both the first main magnet 131 and the second main magnet 132 may include open channels 134.

[0081] In some embodiments, the first main magnet 141 and the second main magnet 142 may be independent. In some embodiments, the accommodation space 133 may be adjustable to facilitate the movement or rotation of the movable supporting device 120 and/or the movement of target objects into and out from the accommodation space 133. Alternatively, the first main magnet 141 and the second main magnet 142 may be connected via a connection element.

[0082] As described elsewhere in the present disclosure, the rotatable gantry of the conventional radiation treatment system is bulky and has a high cost, and the conventional radiation treatment system having a low practicability. Compared with the conventional radiation beam radiation treatment system, the radiation treatment system 200 may achieve radiation treatment from different directions using the movable supporting device 120 instead of using the rotatable gantry, which have a higher flexibility, a smaller size, a lower cost (e.g., a high manufacturing cost, a maintenance cost, etc.), thereby having a high practicability.

[0083] In some embodiments, the radiation treatment device 110 may further include a beam regulator configured to split the initial radiation beam into multiple initial sub-beams transmitting along different directions, or switch (or change) the irradiation direction of the initial radiation beam to a desired direction. Correspondingly, in some embodiments, when the beam splitting regulator is configured to switch (or change) the irradiation direction of the initial radiation beam to a desired direction, the radiation beam adjustor 112 may include multiple adjusting components each of which is configured to adjust a switched initial beam to generate the radiation beam corresponding to a desired direction. In some embodiments, when the beam splitting regulator is configured to split the initial radiation beam into multiple initial sub-beams transmitting along different directions, the radiation beam adjustor 112 may include multiple adjusting components configured to adjust the initial sub-beams, respectively, to generate multiple sub-beams of the radiation beam. In some embodiments, an initial sub-beam may be defocused, focused, shaped, change an irradiation direction, etc., by one of the multiple adjusting components to generate the corresponding sub-beam and enter the target subject. For example, the adjustment component may adjust the irradiation direction of the initial sub-beam so that the generated sub-beam irradiates toward the target region.

In some embodiments, the multiple adjusting components may be of the same type or different types. The multiple sub-beams may irradiate the target region from different directions. In some embodiments, energy levels or shapes of the multiple sub-beams may be the same or different. If the imaging device is an MRI scanner, the irradiation directions of the multiple sub-beams may be parallel to the main magnetic field of the MRI scanner.

[0084] For example, FIG. 4 is a schematic diagram illustrating another exemplary radiation treatment system 400 according to some embodiments of the present disclosure. The difference between the radiation treatment system 400 and the radiation treatment system 200 shown in FIG. 2 is that the radiation treatment device of the radiation treatment system 400 further include a beam regulator 113 configured to split the initial radiation beam into two initial sub-beams transmitting along different directions. The radiation beam adjustor 112 includes adjusting components 1121a and 1121b configured to adjust the two initial sub-beams, respectively, to generate two sub-beams of the radiation beam. The two sub-beams may irradiate the target region from different directions.

[0085] In some embodiments, the beam regulator 113 may include a beam splitting element 1131 and multiple constraint elements 1132. The beam splitting element 1131 may be configured to split the initial radiation beam into the multiple initial sub-beams. In some embodiments, the beam splitting element 1131 may include a magnetic switch. The multiple constraint elements 1132 may be configured to constrain transmission directions of the multiple initial sub-beams so that each of the multiple initial sub-beams enters into one of the multiple adjusting components 1121. In some embodiments, a constraint element 1132 may include a four-pole magnetic switch.

[0086] In some embodiments, the beam regulator 113 may include multiple deflection elements 1133. A deflection element 1133 may be configured to guide an initial sub-beam split by the beam splitting element 1131 into one constraint element 1132 by adjusting a moving direction of the initial sub-beam.

[0087] According to some embodiments of the present disclosure, by using the beam regulator 113, radiation treatment can be delivered to the target region from multiple directions simultaneously, thereby improving the efficiency of the radiation treatment.

[0088] FIG. 3A is a schematic diagram illustrating an exemplary radiation beam emitter 111 according to some embodiments of the present disclosure. As shown in FIG. 3A, the radiation beam emitter 111 may include a radiation beam generator 1111, a radiation beam accelerator 1112,

and one or more guiders 1113. The radiation beam emitter 1111 may be configured to generate the initial radiation beam. The radiation beam accelerator 1112 may be configured to accelerate the initial radiation beam. The one or more guiders 1113 may be configured to guide the accelerated initial radiation beam to enter into the radiation beam adjustor 112. In some embodiments, the radiation beam emitter 111 may further include a deflector 1114. The deflector 1114 may be configured to guide the initial radiation beam generated by the radiation beam emitter 1111 into the radiation beam accelerator 1112 by adjusting a moving direction of the initial radiation beam.

[0089] In some embodiments, the radiation beam accelerator 1112 may include an accelerating element 1112a and a direction control element 1112b. The accelerating element 1112a may be configured to accelerate the initial radiation beam. In some embodiments, the accelerating element 1112a may be a resonant cavity (e.g., a waveguide resonant cavity and a coaxial linear resonant cavity). A volume of the waveguide resonant cavity may be larger than that of the coaxial linear resonant cavity. The coaxial linear resonant cavity may include multiple parallel cavities, and a number of the cavities may be set according to needs, such as the increased energy required for each acceleration.

[0090] The direction control element 1112b may be configured to control a moving direction of the initial radiation beam so that the initial radiation beam returns to the accelerating element 1112a one or more times. In some embodiments, as shown in FIG. 3A, the direction control elements 1112b may include two parts that are symmetrically arranged on both sides of the accelerating element 1112a to guide the initial radiation beam returns to the accelerating element 1112a one or more times. For example, the initial radiation beam may return into the accelerating element 1112a one or more times along one or more annular trajectories (e.g., circular dashed trajectories shown in FIG. 3A). That is, the initial radiation beam may continuously pass through the accelerating element 1112a, each time the initial radiation beam returns into the accelerating element 1112a, it may be accelerated again and its energy level may be increased, and the movement trajectory may be longer than the last movement trajectory. In some embodiments, the direction control element 1112b may include one or more deflection magnets that can deflect the initial radiation beam.

[0091] The one or more guiders 1113 may be located at one or more annular trajectories according to desired energy levels. After a certain time of acceleration, the energy level of the

initial radiation beam may reach a desired level and the initial radiation beam having the desired energy level may be guided out by the one or more guiders 1113.

[0092] In some embodiments, the radiation beam accelerator 1112 may include a microtron. Exemplary microtrons may include a betatron, a petal accelerator, a race track linac, or the like. The microtron has a relatively small size and a low manufacturing cost, thereby reducing the size and the manufacturing cost of the radiation treatment device 110.

[0093] In some embodiments, the initial radiation beam may return into the accelerating element 1112a multiple times along multiple annular trajectories. The one or more guiders 1113 include multiple guiders 1113 disposed on different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels. For example, FIG. 3B is a schematic diagram illustrating another exemplary radiation beam emitter 111 according to some embodiments of the present disclosure. As shown in FIG. 3B, three guiders 1113 are disposed on three annular trajectories for guiding radiation beams with different energy levels. In some embodiments, the one or more guiders 1113 include one or more movable guiders that are capable of moving to different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels. For example, the radiation beam emitter 111 is provided with one or more installation channels, and the one or more movable guiders 1113 are arranged in the one or more installation channels. Positions of the one or more movable guiders 1113 may be adjusted by a control component (e.g., a telescopic cylinder or a telescopic motor).

[0094] In operation, one of the three guiders 1113 may be actuated to guide the radiation beam with a desired level, or two or all of the guiders 1113 may be actuated alternately to guide radiation beams with different energy levels alternately when a multi-energy level radiation beam radiation treatment is performed. In this way, radiation beams with different energy levels may be easily obtained, so that different treatment needs can be satisfied and the accuracy of radiation treatment can be improved.

[0095] In some embodiments, the radiation beam emitter 111 may further include an auxiliary component (e.g., an electromagnet). The auxiliary component may be configured to adjust the movement trajectory of the initial radiation beam and/or assist in accelerating the initial radiation beam, etc.

[0096] FIG. 5 is a schematic diagram illustrating an exemplary radiation treatment system 500

according to some embodiments of the present disclosure. In some embodiments, the radiation treatment system 500 may be an exemplary embodiment of the radiation treatment system 100 as described in connection with FIG. 1.

[0097] As illustrated in FIG. 5, the radiation treatment system 500 may be similar to the radiation treatment system 200 as described in connection with FIG. 2, except that the radiation treatment system 500 may further include a second radiation treatment device 150.

[0098] The second radiation treatment device 150 may be configured to emit a second radiation beam toward the target region of the target subject for the radiation treatment. In some embodiments, the second radiation treatment device 150 may be the same as or similar to the radiation treatment device 110 (also referred to as the first radiation treatment device 110). The radiation beam (also referred to as the first radiation beam) emitted by the first radiation treatment device 110 and the second radiation beam may irradiate the target region from different directions.

[0099] In some embodiments, positions of the first radiation treatment device 110 and the second radiation treatment device 150 may be set according to a type of the imaging device 130, a position of the movable supporting device 120, etc. For example, if the imaging device 130 is an MRI scanner 130A, the irradiation directions of the first radiation beam and the second radiation beam may be parallel to a main magnetic field of the MRI scanner. As another example, the first radiation treatment device 110 and the second radiation treatment device 150 may be symmetrically arranged relative to the movable supporting device 120.

[0100] In some embodiments, energy levels of the first radiation beam and the second radiation beam may be determined based on the position of the target region relative to the first radiation treatment device 110 and the second radiation treatment device 150. For example, if the target region is farther from the first radiation treatment device 110 than from the second radiation treatment device 150, the energy level of the first radiation beam may be greater than the energy level of the second radiation beam. If the target region is closer to the first radiation treatment device 110 than to the second radiation treatment device 150, the energy level of the first radiation beam may be smaller than the energy level of the second radiation beam.

[0101] In some embodiments, the position of the target region relative to the first radiation treatment device 110 and the second radiation treatment device 150 may be determined based on an image of the target region captured by an imaging device (e.g., the MRI scanner 130A) during the

radiation treatment. Specifically, positions of the target subject, the first radiation treatment device 110, and the second radiation treatment device 150 may be obtained. For example, the positions of the target subject, the first radiation treatment device 110, and the second radiation treatment device 150 may be determined based on an optical image captured by an image acquisition device (e.g., a camera). As another example, the positions of the target subject, the first radiation treatment device 110, and the second radiation treatment device 150 may be previously determined. A position of the target region in the target subject may be determined based on the image of the target region. Further, the position of the target region relative to the first radiation treatment device 110 and the second radiation treatment device 150 may be determined based on the position of the target region in the target subject, the positions of the target subject, the first radiation treatment device 110, and the second radiation treatment device.

[0102] The radiation treatment system 500 may use both the first radiation treatment device 110 and the second radiation treatment device simultaneously to perform the radiation treatment on the target subject, which may improve the efficiency of the radiation treatment. In addition, in some embodiments, the energy levels of the first radiation beam and the second radiation beam may be determined based on the position of the target region relative to the first radiation treatment device 110 and the second radiation treatment device 150, which may improve the accuracy of the radiation treatment.

[0103] FIG. 6 is a schematic diagram illustrating an exemplary radiation treatment system 600 according to some embodiments of the present disclosure. In some embodiments, the radiation treatment system 600 may be an exemplary embodiment of the radiation treatment system 100 as described in connection with FIG. 1.

[0104] As illustrated in FIG. 6, the radiation treatment system 600 may be similar to the radiation treatment system 200 as described in connection with FIG. 2, except that the radiation treatment system 600 includes a liftable imaging device 130B different from the MRI scanner 130A of the radiation treatment system 200. The liftable imaging device 130B may include a liftable computed tomography (CT) scanner or a liftable positron emission tomography (PET) scanner.

[0105] The liftable imaging device 130B may include a gantry that can be lifted up or put down. Other components of the liftable imaging device 130B (e.g., an X-ray source, detectors) may be lifted up or put down with the gantry. For example, the gantry may be suspended from a ceiling of a

room where the radiation treatment system 600 is located via a retractable suspension device, and can be lifted up or put down by the retractable suspension device. As shown in FIG. 6, in some embodiments, the gantry of the liftable imaging device 130B has a circular structure, and the movable supporting device 120 is located within an imaging channel of the gantry.

[0106] The gantry of the liftable imaging device 130B may be lifted up when the radiation beam is emitted by the radiation treatment device 110 to avoid blocking the radiation beam. The gantry of the liftable imaging device 130B may be put down and surround the target subject for obtaining the image when the radiation beam is stopped. For example, the radiation beam may be delivered to the target subject multiple times during the radiation treatment. Each time the radiation beam is delivered for a certain period of time, the radiation beam may be stopped and the gantry of the liftable imaging device 130B may be put down and surround the target subject for obtaining the image of the target region. Then, a radiation treatment plan of the radiation treatment may be verified based on the image. Further, the gantry of the liftable imaging device 130B may be lifted up, and then the radiation beam may be delivered to the target subject again according to radiation treatment plan or an updated radiation treatment plan.

[0107] FIG. 7 is a schematic diagram illustrating an exemplary radiation treatment system 700 according to some embodiments of the present disclosure. In some embodiments, the radiation treatment system 700 may be an exemplary embodiment of the radiation treatment system 100 as described in connection with FIG. 1.

[0108] As illustrated in FIG. 7, the radiation treatment system 700 may be similar to the radiation treatment system 200 as described in connection with FIG. 2, except that the radiation treatment system 700 further comprises a converter 160 and a collimator 170 disposed between the radiation treatment device 110 and the movable supporting device 120 (or the MRI scanner 130A).

[0109] The converter 160 may be configured to convert the first radiation beam into a third radiation beam (e.g., a photon beam). The collimator 170 may be configured to adjust the third radiation beam to align to the target region. For example, the collimator 170 may adjust an intensity, shape, etc., of the third radiation beam. The collimator 170 may be a beam-limiting device, such as a multi-leaf collimator, a blocker, that may block a specific portion of the third radiation beam. The specific portion of the third radiation beam may cause dose disposition in the non-target region of the target subject if it is not blocked. In some embodiments, the shape of the

collimator 170 may be adjusted such that the remaining portion of the third radiation beam may be better aligned to the target region.

[0110] In some embodiments, the converter 160 and the collimator 170 may be mounted on the radiation treatment device 110. Alternatively, the converter 160 and the collimator 170 may be mount on another supporting component and be separated from the radiation treatment device 110. In some embodiments, the converter 160 and the collimator 170 may be movable or detachable such that the radiation treatment system 700 may perform the radiation treatment in a similar manner as the radiation treatment system 200. In this way, the radiation treatment system 700 can be used to deliver the third radiation beam and/or the radiation beam for radiation treatments.

[0111] It should be noted that systems and devices illustrated in FIG. 7 and the descriptions thereof are provided for the purposes of illustration, and not intended to limit the scope of the present disclosure. For persons having ordinary skills in the art, various modifications and changes in the forms and details of the application of the above method and system may occur without departing from the principles of the present disclosure. However, those variations and modifications also fall within the scope of the present disclosure. For example, the MRI scanner 130A of the radiation treatment systems 200, 400, 500, 700, and the liftable imaging device 130B of the radiation treatment system 600 may be replaced by another imaging device. As another example, the count of radiation treatment devices may be more than two.

[0112] FIG. 8 is a flowchart illustrating an exemplary process 800 for treating a target subject using a radiation treatment system according to some embodiments of the present disclosure. The radiation treatment system may be any one of the radiation treatment systems 200, 400, 500, 600, and 700 disclosed herein. In some embodiments, the process 800 may be stored in a storage as a form of instructions, and invoked and/or executed by the processing device 140. The operations of the process 800 are intended to be illustrative. In some embodiments, the process 800 may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. Additionally, the order in which the operations of the process 800 is not intended to be limiting.

[0113] In 810, the processing device 140 may cause a radiation treatment to be delivered a target subject according to a radiation treatment plan.

[0114] Specifically, the radiation treatment plan is previously generated based on a planning

image (e.g., a planning CT image) of the target subject and describes how the radiation treatment is going to be performed.

[0115] As described above, the movable supporting device 120 of the radiation treatment system may rotate so that the target subject is irradiated by a radiation beam emitted by the radiation treatment device 110 from multiple directions. The radiation treatment plan may include treatment parameters corresponding to each of the directions. In some embodiments, the treatment parameters corresponding to a specific direction may include planned motion parameters of the movable supporting device 120 and planned beam parameters of the radiation beam corresponding to the direction. The planned motion parameters of the movable supporting device 120 may specify how the movable supporting device 120 moves so that the target subject can be irradiated from the specific directions. Exemplary planned motion parameters of the movable supporting device 120 may include a rotation time (which specifies when the movable supporting device 120 rotates during the radiation treatment), a rotation angle (which specifies the rotation amplitude of the movable supporting device 120), or the like, or any combination thereof. The planned beam parameters may specify what the radiation beam is used to irradiate the target subject under the specific direction. Exemplary planned beam parameters of the radiation beam may include an energy level, a shape, an irradiation direction, an irradiation time, or the like, or any combination thereof.

[0116] As illustrated in FIG. 8, in some embodiments, operation 810 may include operations 811 and 812. In 811, the processing device 140 may cause the radiation treatment device 110 to emit the radiation beam toward the target region of the target subject for radiation treatment according to the radiation treatment plan. In 812, the processing device 140 may cause the movable supporting device 120 to adjust a position of the target region relative to the radiation treatment device 110 according to the radiation treatment plan such that the target region is irradiated by the radiation beam from different directions.

[0117] For example, for each direction, the processing device 140 determine the treatment parameters corresponding to the direction based on the radiation treatment plan. The processing device 140 may cause the movable supporting device 120 to adjust the position of the target region relative to the radiation treatment device 110 according to the planned motion parameters of the movable supporting device 120 corresponding to the direction. Further, the processing device 140 may cause the radiation treatment device 110 to emit the radiation beam toward the target region

according to the planned beam parameters of the radiation beam corresponding to the direction such that the target region is irradiated by the radiation beam from the direction.

[0118] In 820, the processing device 140 may verify the radiation treatment plan in real-time or substantially real-time during the radiation treatment. For example, the verification of the radiation treatment plan may be used to compensate for motion (e.g., physiological motion, rigid body motion) of the target subject during the radiation treatment. Specifically, operation 820 may include operations 821 and 822 as shown in FIG. 8. In 821, the processing device 140 may cause the imaging device 130 to collect one or more images of the target region during the radiation treatment. In 822, the processing device 140 may determine whether the radiation treatment plan needs to be adjusted based on the one or more images.

[0119] For example, each time the imaging device 130 collect a current image. The processing device 140 may determine a current feature of the target region based on the current image of the target region. Exemplary features of the target region may include a position, a shape, a size, etc., of the target region. The processing device 140 may determine whether a difference between the current feature of the target region and a historical feature of the target region in a historical image exceeds a preset threshold. The historical image may be the last image collected by the imaging device 130 or the previous image collected by the imaging device 130 when the radiation beam is adjusted last time. For example, the processing device 140 may determine whether a size difference between the current size of the target region and a historical size of the target region in the historical image exceeds a size threshold. In response to determining that the difference exceeds the preset threshold (e.g., the size difference exceeds the size threshold), the processing device 140 may determine that the radiation treatment plan needs to be adjusted, and adjust the radiation treatment plan such that the current target region can be targeted by the radiation beam. For example, the planned beam parameters (e.g., the irradiation direction, the shape, the energy level) of the radiation beam in the radiation treatment plan may be adjusted based on the current feature of the target region. As another example, the planned motion parameters of the movable supporting device 120 may be adjusted based on the current feature of the target region.

[0120] After the radiation treatment plan is adjusted, the radiation treatment may be delivered according to the adjusted radiation treatment plan. For example, the radiation beam may be emitted according to the adjusted beam parameters and/or the movable supporting device 120 may

move according to the adjusted motion parameters. The real-time adjustment of the treatment plan may improve the aligning of the radiation beam to the current target region to improve the treatment accuracy.

[0121] Having thus described the basic concepts, it may be rather apparent to those skilled in the art after reading this detailed disclosure that the foregoing detailed disclosure is intended to be presented by way of example only and is not limiting. Various alterations, improvements, and modifications may occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested by this disclosure, and are within the spirit and scope of the exemplary embodiments of this disclosure.

[0122] Moreover, certain terminology has been used to describe embodiments of the present disclosure. For example, the terms “one embodiment,” “an embodiment,” and/or “some embodiments” may mean that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Therefore, it is emphasized and should be appreciated that two or more references to “an embodiment” or “one embodiment” or “an alternative embodiment” in various portions of this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures or characteristics may be combined as suitable in one or more embodiments of the present disclosure.

[0123] Further, it will be appreciated by one skilled in the art, aspects of the present disclosure may be illustrated and described herein in any of a number of patentable classes or context including any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof. Accordingly, aspects of the present disclosure may be implemented entirely hardware, entirely software (including firmware, resident software, micro-code, etc.) or combining software and hardware implementation that may all generally be referred to herein as a “unit,” “module,” or “system.” Furthermore, aspects of the present disclosure may take the form of a computer program product embodied in one or more computer readable media having computer readable program code embodied thereon.

[0124] Furthermore, the recited order of processing elements or sequences, or the use of numbers, letters, or other designations therefore, is not intended to limit the claimed processes and methods to any order except as may be specified in the claims. Although the above disclosure

discusses through various examples what is currently considered to be a variety of useful embodiments of the disclosure, it is to be understood that such detail is solely for that purpose, and that the appended claims are not limited to the disclosed embodiments, but, on the contrary, are intended to cover modifications and equivalent arrangements that are within the spirit and scope of the disclosed embodiments. For example, although the implementation of various components described above may be embodied in a hardware device, it may also be implemented as a software only solution, for example, an installation on an existing server or mobile device.

[0125] Similarly, it should be appreciated that in the foregoing description of embodiments of the present disclosure, various features are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure aiding in the understanding of one or more of the various inventive embodiments. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed object matter requires more features than are expressly recited in each claim. Rather, inventive embodiments lie in less than all features of a single foregoing disclosed embodiment.

[0126] In some embodiments, the numbers expressing quantities or properties used to describe and claim certain embodiments of the application are to be understood as being modified in some instances by the term “about,” “approximate,” or “substantially.” For example, “about,” “approximate,” or “substantially” may indicate $\pm 1\%$, $\pm 5\%$, $\pm 10\%$, or $\pm 20\%$ variation of the value it describes, unless otherwise stated. Accordingly, in some embodiments, the numerical parameters set forth in the written description and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by a particular embodiment. In some embodiments, the numerical parameters should be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of some embodiments of the application are approximations, the numerical values set forth in the specific examples are reported as precisely as practicable.

[0127] Each of the patents, patent applications, publications of patent applications, and other material, such as articles, books, specifications, publications, documents, things, and/or the like, referenced herein is hereby incorporated herein by this reference in its entirety for all purposes, excepting any prosecution file history associated with same, any of same that is inconsistent with or

in conflict with the present document, or any of same that may have a limiting effect as to the broadest scope of the claims now or later associated with the present document. By way of example, should there be any inconsistency or conflict between the description, definition, and/or the use of a term associated with any of the incorporated material and that associated with the present document, the description, definition, and/or the use of the term in the present document shall prevail.

[0128] In closing, it is to be understood that the embodiments of the application disclosed herein are illustrative of the principles of the embodiments of the application. Other modifications that may be employed may be within the scope of the application. Thus, by way of example, but not of limitation, alternative configurations of the embodiments of the application may be utilized in accordance with the teachings herein. Accordingly, embodiments of the present application are not limited to that precisely as shown and described.

WHAT IS CLAIMED IS:

1. A radiation treatment system, comprising:

a radiation treatment device configured to emit a radiation beam toward a target region of a target subject for radiation treatment; and

a movable supporting device for supporting the target subject, wherein the movable supporting device is configured to adjust a position of the target region relative to the radiation treatment device during the radiation treatment such that the target region is irradiated by the radiation beam from different directions.

2. The system of claim 1, wherein an irradiation direction of the radiation beam is substantially fixed.

3. The system of claim 1, wherein the movable supporting device is rotatable such that the target region is able to be irradiated by the radiation beam from any angle.

4. The system of claim 1, wherein the radiation beam is an electron beam, and an energy level of the electron beam is greater than 50 megaelectron volts (MeV).

5. The system of any one of claims 1-4, wherein the movable supporting device is rotatable to change an orientation of the target region.

6. The system of any one of claims 1-5, wherein

the system further includes an imaging device configured to obtain one or more images of the target region during the radiation treatment.

7. The system of claim 6, wherein

the imaging device includes a magnetic resonance imaging (MRI) scanner.

8. The system of claim 7, wherein

an irradiation direction of the radiation beam is substantially parallel to a main magnetic field of the MRI scanner;

9. The system of claim 7 or 8, wherein

the MRI scanner includes a first main magnet, a second main magnet that is disposed opposite to the first main magnet, and an accommodation space between the first main magnet and the second main magnet for accommodating the target subject and the movable supporting device, and at least one of the first main magnet or the second main magnet includes an open channel for the radiation beam to pass through to irradiate the target region.

10. The system of claim 6, wherein

the imaging device includes a liftable computed tomography (CT) scanner or a liftable positron emission tomography (PET) scanner.

11. The system of claim 10, wherein

a gantry of the liftable CT scanner or the liftable PET scanner is lifted up when the radiation beam is emitted by the radiation treatment device, and the gantry of the liftable CT scanner or the liftable PET is put down and surrounds the target subject for obtaining the image when the radiation beam is stopped.

12. The system of any one of claims 1-11, wherein the radiation treatment device comprises:

a radiation beam emitter configured to emit an initial radiation beam; and a radiation beam adjustor configured to adjust the shape and/or direction of the initial radiation beam to generate the radiation beam that aligns to the target region.

13. The system of claim 12, wherein the radiation beam emitter is located at a fixed location for emitting the initial radiation beam along a fixed direction.

14. The system of claim 12, wherein the radiation beam adjustor includes one of:

a scanning magnet that adjusts the initial radiation beam via a magnetic field;
a microwave cavity that adjusts the initial radiation beam by applying a microwave field;

an electric field applying device that adjusts the initial radiation beam by applying an electric field.

15. The system of claim 12, wherein the radiation beam emitter includes a radiation beam generator, a radiation beam accelerator, and one or more guiders, wherein

the radiation beam generator is configured to generate the initial radiation beam;

the radiation beam accelerator is configured to accelerate the initial radiation beam, the radiation beam accelerator including an accelerating element and a direction control element, the accelerating element being configured to accelerate the initial radiation beam, the direction control element being configured to control a moving direction of the initial radiation beam so that the initial radiation beam returns to the accelerating element at least one time; and

the one or more guiders are configured to guide the initial radiation beam to enter into the radiation beam adjustor.

16. The system of claim 15, wherein the radiation beam accelerator includes a microtron.

17. The system of claim 16, wherein the microtron is one of a betatron, a petal accelerator, and a race track linac.

18. The system of claim 15, wherein

the initial radiation beam returns into the accelerating element multiple times along multiple annular trajectories,

the one or more guiders include multiple guiders disposed on different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels.

19. The system of claim 15, wherein

the initial radiation beam returns into the accelerating element multiple times along multiple annular trajectories,

the one or more guiders include one or more movable guiders that are capable of moving to different annular trajectories of the multiple annular trajectories for guiding radiation beams with different energy levels.

20. The system of any one of claims 12-19, wherein

the radiation treatment device further includes a beam regulator configured to split the initial radiation beam into multiple initial sub-beams transmitting along different directions,

the radiation beam adjustor includes multiple adjusting component configured to adjust the initial sub-beams, respectively, to generate multiple sub-beams of the radiation beam, the multiple sub-beams irradiating the target region from different directions.

21. The system of claim 20, wherein the beam regulator includes:

a beam splitting element configured to split the initial radiation beam into the multiple initial sub-beams;

multiple constraint elements configured to constrain transmission directions of the multiple initial sub-beams so that each of the multiple initial sub-beams enters into one of the multiple adjusting components.

22. The system of any one of claims 1-21, wherein the system further comprises a second radiation treatment device configured to emit a second radiation beam toward the target region of the target subject for the radiation treatment, the radiation beam and the second radiation beam irradiating the target region from different directions.

23. The system of claim 22, wherein energy levels of the radiation beam and the second radiation beam are determined based on the position of the target region relative to the radiation treatment device and the second radiation treatment device.

24. The system of claim 23, wherein the position of the target region relative to the radiation treatment device and the second radiation treatment device is determined based on an image of the target region captured by an imaging device during the radiation treatment.

25. The system of any one of claims 1-24, wherein

the system further comprises a converter and a collimator disposed between the radiation treatment device and the movable supporting device,

the converter is configured to convert the radiation beam into a third radiation beam, and

the collimator is configured to adjust the third radiation beam to align to the target region.

26. A method for treating a target subject using a radiation treatment system, the radiation treatment system comprising a radiation treatment device, a movable supporting device, an imaging device, wherein the method is implemented on a computing device having at least one processor and at least one storage device and comprises:

causing a radiation treatment to be delivered a target subject according to a radiation treatment plan by:

causing the radiation treatment device to emit a radiation beam toward a target region of a target subject for radiation treatment according to the radiation treatment plan;

causing the movable supporting device to adjust a position of the target region relative to the radiation treatment device according to the treatment plan such that the target region is irradiated by the radiation beam from different directions;

verifying the radiation treatment plan in real-time during the radiation treatment by:

causing the imaging device to collect one or more images of the target region during the radiation treatment; and

determining, based on the one or more images, whether the radiation treatment plan needs to be adjusted.

27. A non-transitory computer readable medium, comprising at least one set of instructions for treating a target subject using a radiation treatment system, the radiation treatment system comprising a radiation treatment device, a movable supporting device, an imaging device, wherein when executed by one or more processors of a computing device, the at least one set of instructions causes the computing device to perform a method, the method comprising:

causing a radiation treatment to be delivered a target subject according to a radiation treatment plan by:

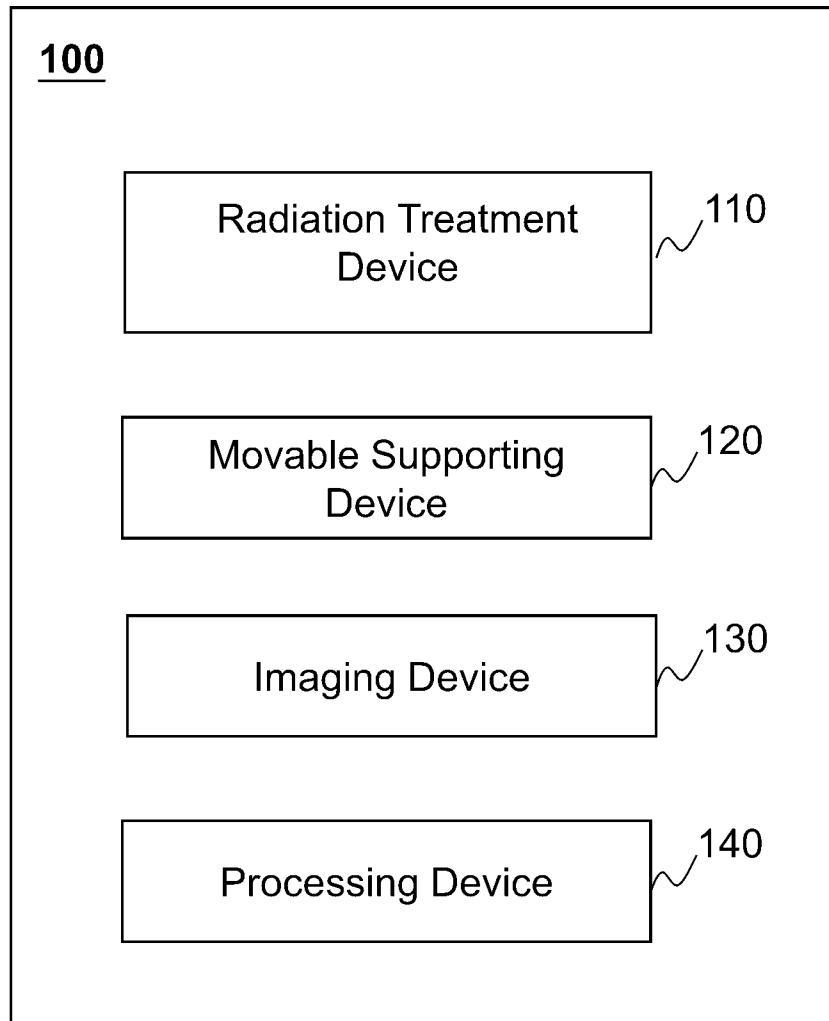
causing the radiation treatment device to emit a radiation beam toward a target region of a target subject for radiation treatment according to the radiation treatment plan;

causing the movable supporting device to adjust a position of the target region relative to the radiation treatment device according to the treatment plan such that the target region is irradiated by the radiation beam from different directions;

verifying the radiation treatment plan in real-time during the radiation treatment by:

causing the imaging device to collect one or more images of the target region during the radiation treatment; and

determining, based on the one or more images, whether the radiation treatment plan needs to be adjusted.

**FIG. 1**

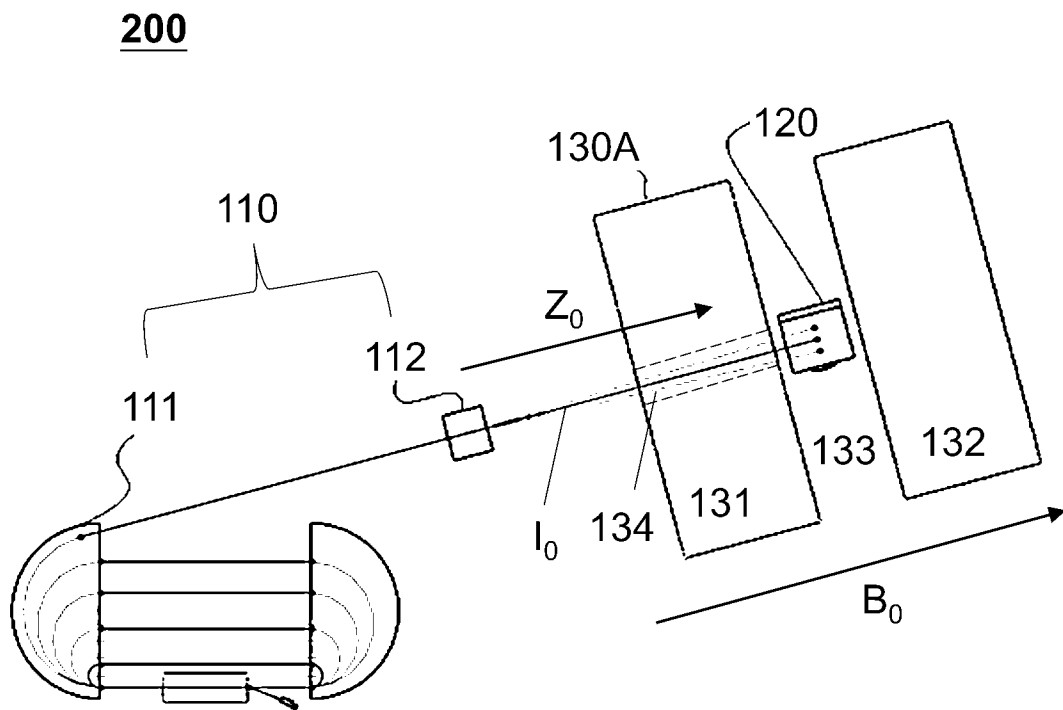
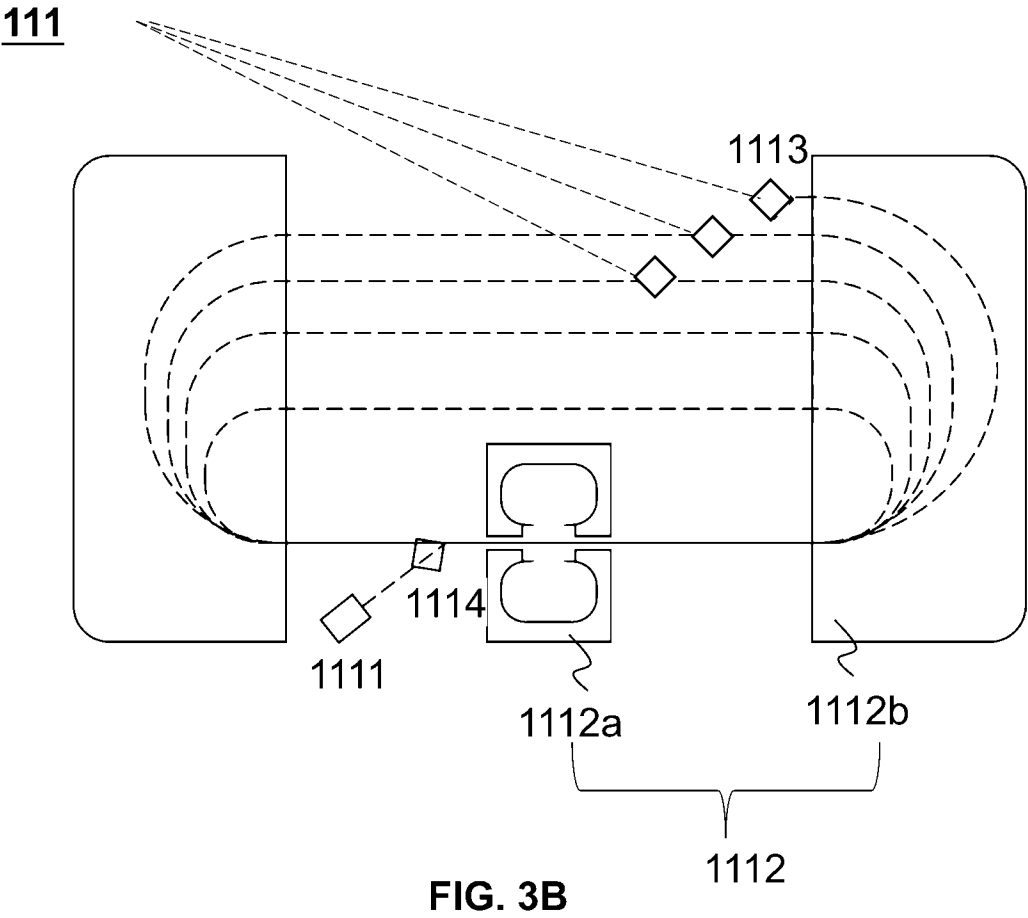
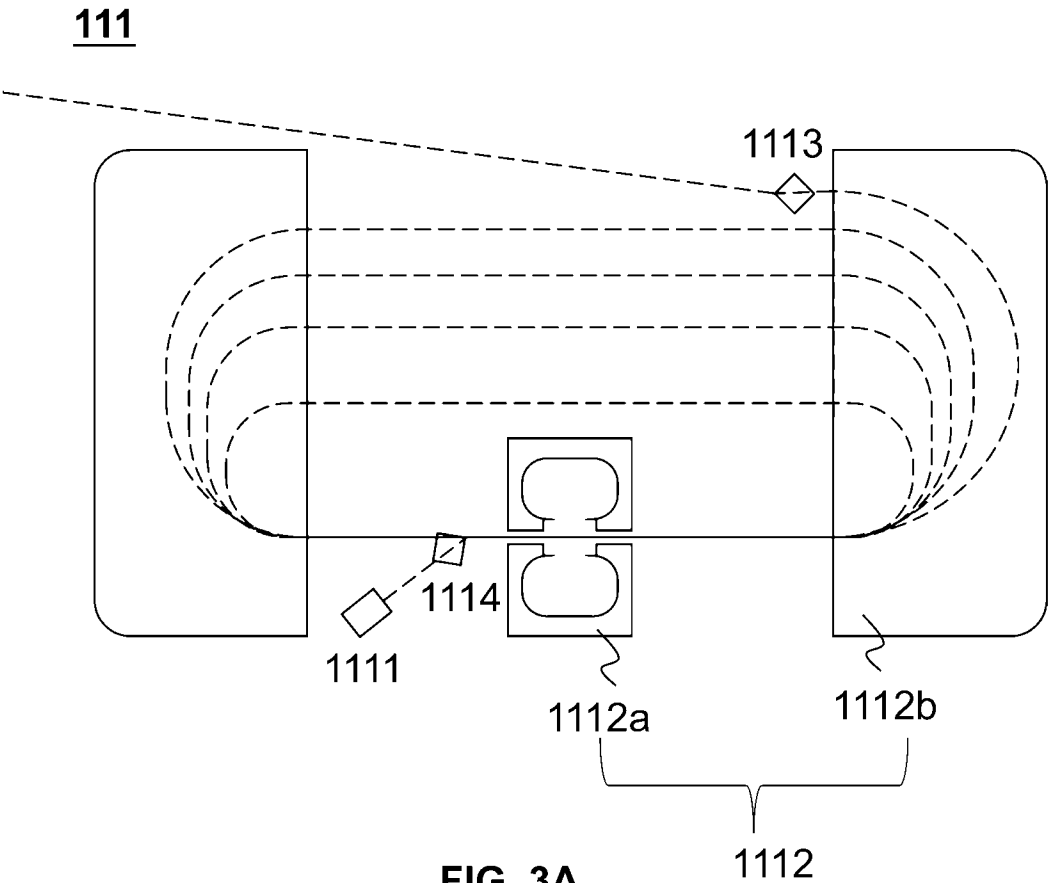


FIG. 2



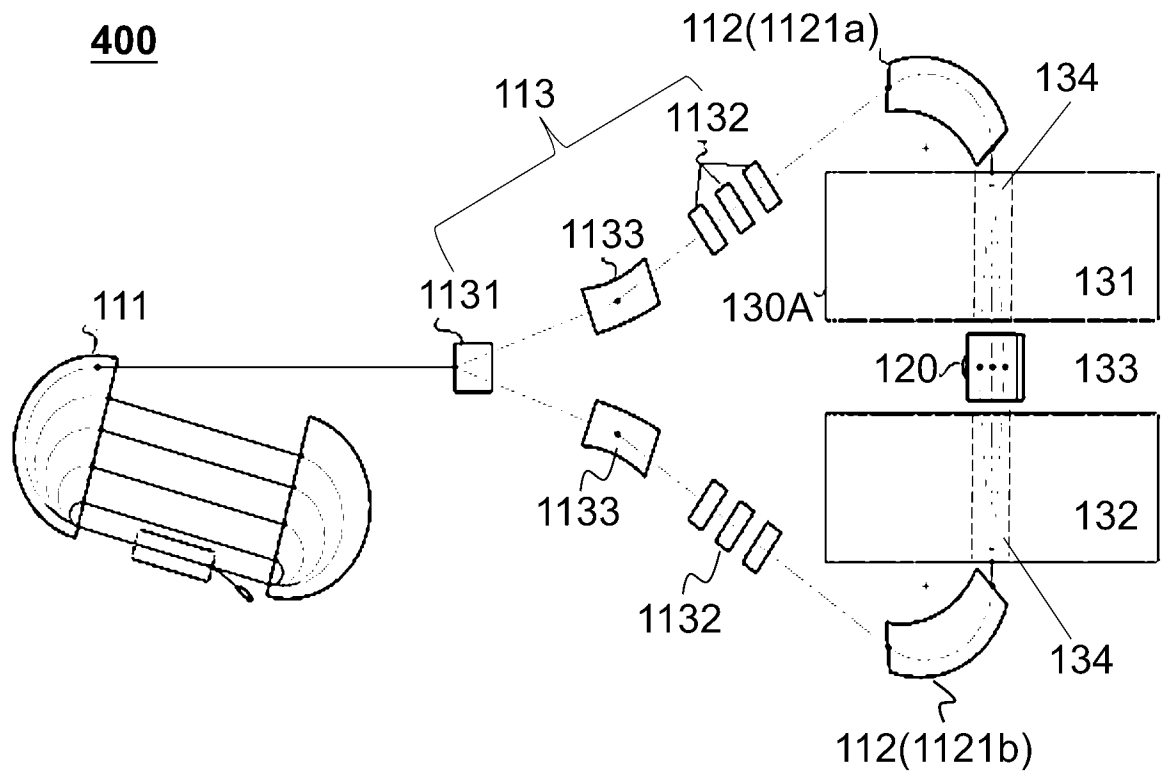


FIG. 4

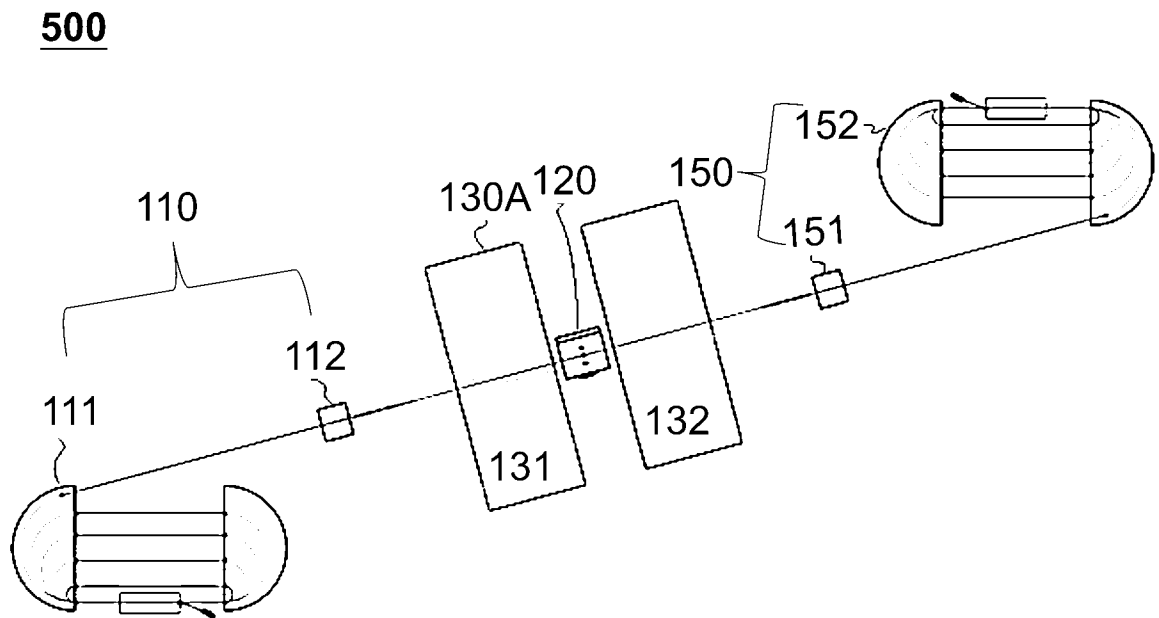


FIG. 5

600

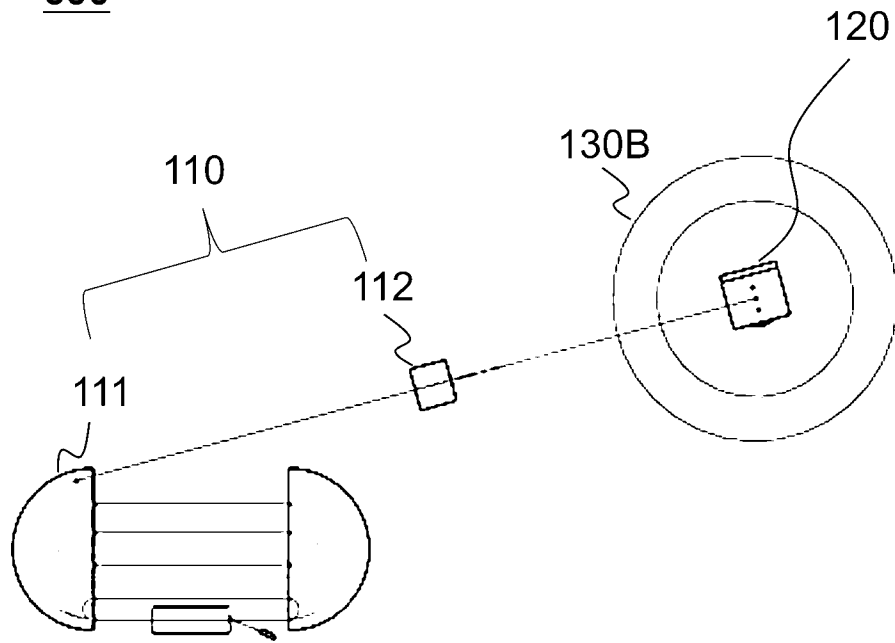


FIG. 6

700

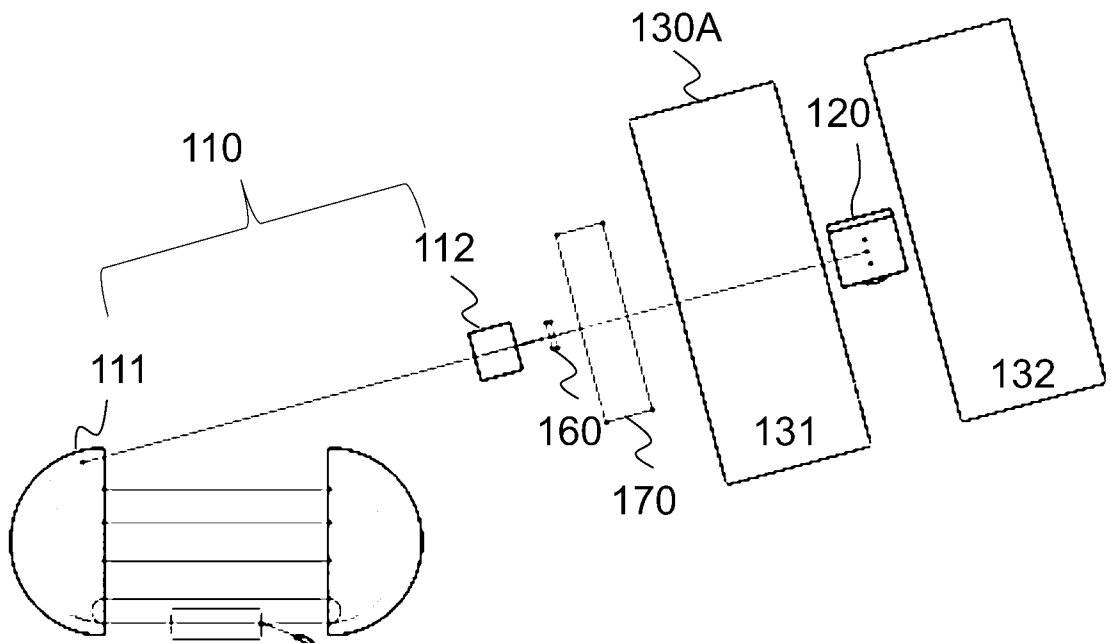
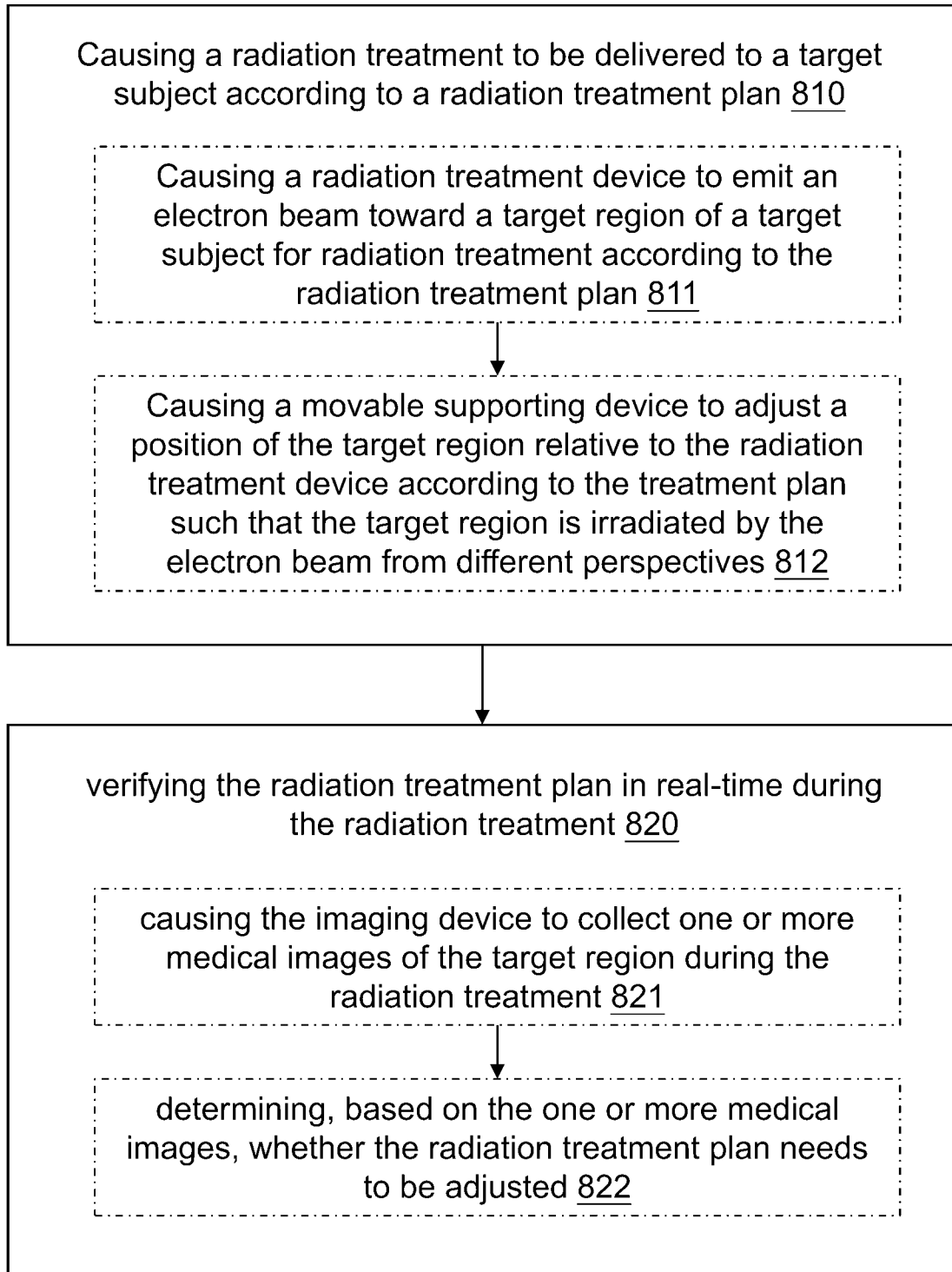


FIG. 7

800**FIG. 8**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/074785

A. CLASSIFICATION OF SUBJECT MATTER A61N5/10(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC: A61N Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT,ENTXTC,CNKI,DWPI,WPABS: shanghai united imaging healthcare, wang peng, ni cheng, radiate, treatment, therapeutic,beam, target, rotate, support, couch, bed, chair, move, adjust, irradiate		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007274446 A1 (EASTMAN KODAK COMPANY) 29 November 2007 (2007-11-29) description, paragraphs [0037]-[0050] and figures 1-16	1-3,5-6,10-13, 20-21,26-27
Y	US 2007274446 A1 (EASTMAN KODAK COMPANY) 29 November 2007 (2007-11-29) description, paragraphs [0037]-[0050] and figures 1-16	4,7-9,14-19,22-25
Y	US 2023113808 A1 (SHANGHAI UNITED IMAGING HEALTHCARE CO., LTD.) 13 April 2023 (2023-04-13) description, paragraphs [0037], [0068]-[0071]	4,7-9,14-19,22-25
A	CN 101065162 A (SIEMENS A.G.) 31 October 2007 (2007-10-31) the whole document	1-27
A	JP 2000107303 A (SIEMENS MEDICAL SYSTEMS INC.) 18 April 2000 (2000-04-18) the whole document	1-27
A	CN 101347656 A (SIEMENS A.G.) 21 January 2009 (2009-01-21) the whole document	1-27
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “D” document cited by the applicant in the international application “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search 10 May 2024		Date of mailing of the international search report 15 May 2024
Name and mailing address of the ISA/CN CHINA NATIONAL INTELLECTUAL PROPERTY ADMINISTRATION 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China		Authorized officer LI,YinCen Telephone No. (+86) 010-53962490

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/074785

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2024/074785

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				DE	102008007245 B4	14 October 2010
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				US	8958864 B2	17 February 2015
				CL	2008000604 A1	20 June 2008
US	2013142310	A1	06 June 2013	None		