(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 586 744 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.07.2025 Bulletin 2025/29

(21) Application number: **24150986.8**

(22) Date of filing: **09.01.2024**

(51) International Patent Classification (IPC):
H05G 1/02 *(2006.01)* ***H05G 1/10*** *(2006.01)*
H01J 35/16 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H05G 1/02; H05G 1/025; H05G 1/10; H01J 35/165

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(54) TUBE IN TUBE INSERT FOR MOBILE X-RAY AND DXR SYSTEM

(57) The present invention relates to X-ray sources. In order to provide an X-ray source that is compatible for different types of systems, a modular X-ray source system (100) is provided that comprises at least one X-ray tube module (10) comprising an X-ray generating arrangement including a cathode and an anode, a vacuum housing enclosing the X-ray generating arrangement in an enclosure, and a dock interface; and a plurality of tube docks (110) of at least two different dock types, each dock type being configured to provide at least one different functionality, selectively attachable to the dock interface of the at least one X-ray tube module for operating the at least one X-ray tube module.

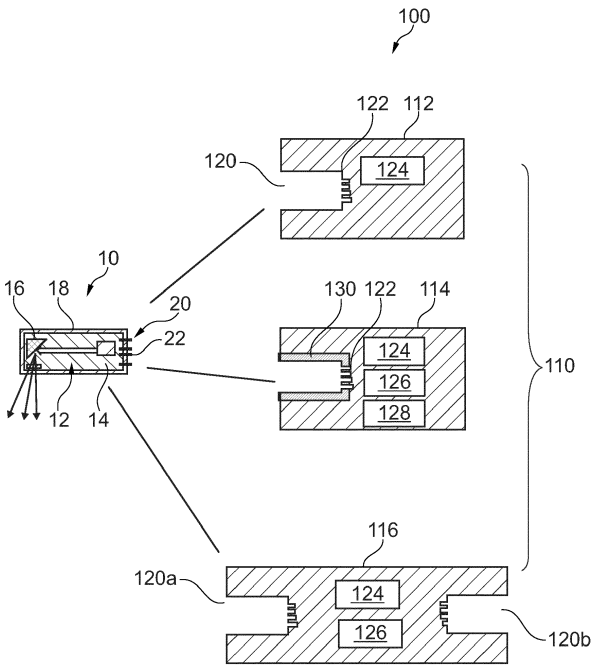

Fig. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to X-ray sources, and in particular to a modular X-ray source system, and to a method of using the modular X-ray source system.

BACKGROUND OF THE INVENTION

[0002] X-ray tubes have a number of applications which involve the treatment or analysis of a sample, for example, industrial imaging, analytical instruments and medical imaging. Various types of X-ray tubes have been developed to meet different performance requirements demanded by these applications. For example, for small mobile X-ray systems often only low X-ray power is required and also the required heat capacity including cooling capabilities would be lower compared to standard Digital X-ray Radiogrammetry (DXR) X-ray systems.

SUMMARY OF THE INVENTION

[0003] There may be a need to provide an X-ray source system that is compatible for different types of systems.

[0004] The object of the present invention is solved by the subject-matter of the independent claims, wherein further embodiments are incorporated in the dependent claims. It should be noted that the following described aspects of the invention apply also for the modular X-ray source system, and the method of using the modular X-ray source system.

[0005] According to a first aspect of the present invention, there is provided a modular X-ray source system. The modular X-ray source system comprises at least one X-ray tube module comprising an X-ray generating arrangement including a cathode and an anode, a vacuum housing enclosing the X-ray generating arrangement in an enclosure, and a dock interface. The modular X-ray source system further comprises a plurality of tube docks of at least two different dock types, each dock type being configured to provide at least one different functionality, selectively attachable to the dock interface of the at least one X-ray tube module for operating the at least one X-ray tube module.

[0006] Accordingly, a modular X-ray source system is proposed to have a compatible modular tube design for use in different types of X-ray systems. The modular X-ray source system has at least one X-ray tube module and a plurality of tube docks of different types. The at least one X-ray tube module is selectively attachable to one of the plurality of tube docks to form an X-ray source to meet different performance requirements demanded different X-ray systems.

[0007] As an example, the plurality of tube docks may comprise the following three exemplary dock types.

[0008] The first dock type may be a simple tube dock that just provides mains power and mandatory control electronics to the at least one X-ray tube module allowing only few low power shots. In other words, a tube dock of the first dock type may be provided with a basic low power functionality for mobile imaging. The at least one X-ray tube module may be attached to a tube dock of the first dock type to achieve a compact stand-alone module in a mobile X-ray setting. For the mobile setting the basic lightweight small X-ray tube module would be a fully functional base unit.

[0009] The second dock type may be a tube dock with liquid cooling and/or extra high voltage generator, allowing to use the at least one X-ray tube module in a high power mode and/or for longer scans. The at least one X-ray tube module may be attached to a tube dock of the second type with additional infrastructure, e.g., additional cooling capacity, energy buffering, and additional control electronics. This configuration may be used in a standard DXR setting with higher power usage.

[0010] The third dock type may be a tube dock with at least two tube interfaces to use two or more X-ray tube modules at the same time. The "multi-tube-docks" with several X-ray tube modules may be used as multi-focus and multi-functional tubes, allowing to either cover a wider Field of View (FOV) or to provide some depth resolution like in tomosynthesis.

[0011] The usage of such a modular base unit in various X-ray systems may allow for cheaper systems and also for simple self-replacement of the X-ray tube module in case of defects or component aging. Easy service and replacement and cheap modular concept using the same X-ray tube module may allow for a modular and upgradable design.

[0012] According to an exemplary embodiment of the first aspect of the present invention, the at least one different functionality comprises a heat management functionality to provide thermal management for the at least one X-ray tube module.

[0013] Accordingly, at least one tube dock in the plurality of tube docks may have an extended heat capacity via a cooling infrastructure allowing to use the at least one X-ray tube module in a mobile setting. A liquid cooling system may be added, allowing to use the at least one X-ray tube module in a high power mode and/or for longer scans.

[0014] According to an exemplary embodiment of the first aspect of the present invention, the plurality of tube docks comprises at least one tube dock with a cooling arrangement configured to provide passive cooling of the at least one X-ray tube module, and/or a cooling system configured to direct a flow of coolant proximate to the at least one X-ray tube module so that the coolant removes at least some heat therefrom.

[0015] According to an exemplary embodiment of the first aspect of the present invention, at least one different functionality comprises a radiation shielding functionality to shield the at least one X-ray tube module.

[0016] The additional radiation shielding functionality may be beneficial when the at least one X-ray tube is used

in a high power mode and/or for longer scans.

[0017] According to an exemplary embodiment of the first aspect of the present invention, the plurality of tube docks comprises at least one tube dock with a radiation shielding arrangement.

[0018] According to an exemplary embodiment of the first aspect of the present invention, at least one different functionality comprises a high voltage supply functionality for supplying a high voltage to the at least one X-ray tube module.

[0019] Accordingly, additional energy buffering is provided to ensure that the at least one X-ray tube module works properly in a high power mode.

[0020] According to an exemplary embodiment of the first aspect of the present invention, the plurality of tube docks comprises at least one tube dock with a high voltage generator configured to supply the at least one X-ray tube module with a required high voltage, and/or a high voltage generator interface configured to be electrically connectable to an external high voltage generator that is configured to supply the at least one X-ray tube module with a required high voltage.

[0021] According to an exemplary embodiment of the first aspect of the present invention, the plurality of tube docks comprises at least one tube dock with a tube alignment guide that is configured to permit free axial movement of the at least one X-ray tube module while restricting at least one of lateral movement and angular movement of the at least one X-ray tube module.

[0022] In this way, it is possible to allow simple replacement of the X-ray tube module by non-expert for maintenance and adaption of the modular X-ray system via selection of the types of X-ray tube module.

[0023] According to an exemplary embodiment of the first aspect of the present invention, the plurality of tube docks comprises at least one tube dock configured to be attachable to two or more X-ray tube modules.

[0024] Accordingly, the "multi-tube-docks" with several X-ray tube modules may be used as multi-focus and multi-functional tubes, allowing to either cover a wider FOV or to provide some depth resolution like in tomosynthesis.

[0025] According to an exemplary embodiment of the first aspect of the present invention, the at least one X-ray tube module comprises a plurality of X-ray tube modules of at least two different tube types, each tube type having at least one different tube characteristic, selectively attachable to the at least one of the plurality tube docks.

[0026] Accordingly, it is possible to select an X-ray tube module with a tube characteristic meeting the requirement of a particular X-ray system.

[0027] According to an exemplary embodiment of the first aspect of the present invention, the at least one different tube characteristic comprises one or more of:

- a different tube material;
- a different focal spot size;
- a different focal spot location;
- a different anode angle;
- a different power capability; and
- a different number of filaments of the cathode.

[0028] According to an exemplary embodiment of the first aspect of the present invention, the modular X-ray source system further comprises an X-ray source arrangement comprising two or more of the plurality of tube docks arranged in a predetermined geometry, each tube dock being attached to one or more X-ray tube modules.

[0029] Accordingly, the X-ray source system may be configured to cover a wider FOV. Additionally, each tube dock and X-ray tube module in the X-ray source arrangement may be selected to generate different X-rays at different positions to meet the requirement of a special application.

[0030] According to a second aspect of the present invention, there is provided a method of using the modular X-ray source system according to the first aspect and any associated example for generating X-ray radiation for an X-ray system, the method comprising:

a) providing at least one X-ray tube module;
b) providing at least one tube dock; and
c) attaching the at least one X-ray tube module to the at least one tube dock for X-ray generation.

[0031] Accordingly, the usage of such a modular base unit in various X-ray systems may allow for cheaper systems and also for simple self-replacement of the X-ray tube module in case of defects or component aging. Easy service and replacement and cheap modular concept using the same X-ray tube module may allow for a modular and upgradable design.

[0032] According to an exemplary embodiment of the first aspect of the present invention, step a) further comprises:

a1) providing a plurality of X-ray tube modules having different tube characteristics; and
a2) selecting one X-ray tube module from the plurality of X-ray tube modules based on a performance requirement demanded by the X-ray system; and

wherein step c) further comprises:

- attaching the selected X-ray tube module to the at least one tube dock for X-ray generation.

According to an exemplary embodiment of the first aspect of the present invention, step b) further comprises:

b1) providing a plurality of tube docks of different dock types, each dock type providing at least one different functionality; and
b2) selecting one tube dock from the plurality of tube docks based on a performance requirement demanded by the X-ray system; and

wherein step c) further comprises:

- attaching the at least one X-ray tube module to the selected tube dock for X-ray generation.

[0033] These and other aspects of the present invention will become apparent from and be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] These and other aspects of the invention will be apparent from and elucidated further with reference to the embodiments described by way of examples in the following description and with reference to the accompanying drawings, in which

Fig. 1 illustrates an exemplary modular X-ray source system

Fig. 2 illustrates an exemplary X-ray source that is formed by attaching the X-ray tube module to a tube dock of a first dock type.

Fig. 3A illustrates an exemplary X-ray source that is formed by attaching the X-ray tube module to a tube dock of a second dock type.

Fig. 3B illustrates an exemplary cooling system for the X-ray source shown in FIG. 3A.

Fig. 4 illustrates an exemplary X-ray source that is formed by attaching the X-ray tube module to a tube dock of a third dock type.

Fig. 5 illustrates a further example of the modular X-ray source system.

Fig. 6 illustrates an exemplary X-ray source arrangement

Fig. 7 illustrates a flowchart describing a method of using the modular X-ray source system for generating X-ray radiation for an X-ray system.

[0035] It should be noted that the figures are purely diagrammatic and not drawn to scale. In the figures, elements which correspond to elements already described may have the same reference numerals. Examples, embodiments or optional features, whether indicated as nonlimiting or not, are not to be understood as limiting the invention as claimed.

DETAILED DESCRIPTION OF EMBODIMENTS

[0036] Fig. 1 illustrates an exemplary modular X-ray source system 100. The exemplary modular X-ray source system 100 comprises an X-ray tube module 10. The at least one X-ray tube module 10 comprises an X-ray generating arrangement 12 including a cathode 14 that has an electron emission source configured to emit electrons and an anode 16 that generates X-rays by collision of electrons. The anode 16 may be a stationary anode or a rotatory anode. Although not shown, an optional second cathode might be used only in in a high power mode, e.g., in the DXR plug-in mode, when additional infrastructure is connected to the X-ray tube module 10 in the extension housing. The X-ray tube module 10 further comprises a vacuum housing 18 enclosing the X-ray generating arrangement 12 in an enclosure. The X-ray tube module 10 further comprises a dock interface 20. As shown in Fig. 1, the dock interface 20 may comprise one or more electric interface connections 22 configured to electrically connect the at least one X-ray tube to one of the plurality of tube docks 110.

[0037] The exemplary modular X-ray source system 100 further comprises a plurality of tube docks 110 of at least two different dock types, which are selectively attachable to the dock interface 20 of the X-ray tube module for operating the X-ray tube module. Each dock type is configured to provide at least one different functionality. Examples of the different functionality may include, but are not limited to, a heat management functionality to provide thermal management for the X-ray tube module, a radiation shielding functionality to shield the X-ray tube module, a high voltage supply functionality for supplying a high voltage to the X-ray tube module, and a functionality to connect the tube dock to two or more X-ray tube modules.

[0038] In the illustrated example, the plurality of tube docks 120 comprises three tube docks 112, 114, 116 of three different dock types. While a limited number of tube docks are illustrated by way of example, it will be appreciated that the plurality of tube docks 120 may comprise more than three tube docks.

[0039] The exemplary tube dock 112 of a first dock type may be configured to provide some basic functionalities. For example, as shown in Fig. 1, the exemplary tube dock 112 may comprise an X-ray tube interface 120. The X-ray tube interface 120 may comprise one or more electric interface connections 122 that are electrically connectable to the one or more electrical interface connections 22 of the X-ray tube module 10. The exemplary tube dock 112 may further comprise control electronics 124 configured to control an operation of the X-ray tube module 10. In some implementations, the control electronic 124 of the exemplary tube dock 112 may comprise only basic control electronics that is mandatory for the operation of the X-ray tube module 10. In some implementations, the tube dock 112 of the first type may comprise a cooling arrangement configured to provide passive cooling of the at least one X-ray tube module. For example, a cooling pack may be used as simplified cooling option in the mobile scenario.

[0040] Fig. 2 illustrates an exemplary X-ray source that is formed by attaching the X-ray tube module 10 to the tube dock 112 of the first dock type. In this illustrated example, the exemplary tube dock 112 of the first dock type may be configured to provide mains power and control electronics 124 to the X-ray tube module 10. Such configuration may be used for a mobile X-ray having few X-ray shots without overheating.

[0041] Turning back to Fig. 1, the exemplary tube dock

114 of a second dock type may be configured to provide one or more additional functionalities. For example, compared to the tube dock 112 of the first type, the exemplary tube dock 114 of the second type may further provide a high voltage supply functionality for supplying a high voltage to the at least one X-ray tube module. For example, the tube dock 114 of the second type may comprise a high voltage generator 126 configured to supply the X-ray tube module 10 with a required high voltage. Alternatively or additionally, the tube dock 114 may comprise a high voltage generator interface (not shown) configured to be electrically connectable to an external high voltage generator that is configured to supply the X-ray tube module 10 with a required high voltage. In some implementations, the tube dock 114 of the second type may further provide a heat management functionality to provide thermal management for the at least one X-ray tube module. For example, the tube dock 114 shown in Fig. 1 may further comprise a cooling system 128 configured to direct a flow of coolant proximate to the at least one X-ray tube module so that the coolant removes at least some heat therefrom. For example, liquid cooling may be used in the tube dock 114 to have improved cooling down in the X-ray tube module 10. In these implementations, there may be no need to provide a special cooling infrastructure in the X-ray tube module 10. A special heat guiding mechanism may be provided at the anode to a housing-interface-area to improve the heat flow to the outside of the X-ray tube module 10 where the tube dock 114 may have a cooling interface.

[0042] In some examples, the tube dock 114 of the second type may be configured to provide a radiation shielding functionality to shield the X-ray tube module 10. For example, as shown in Fig. 1, the tube dock 114 of the second type may comprise a radiation shielding arrangement 130 which may be a layer of lead arranged to shield the X-ray tube module 10.

[0043] While Fig. 1 may show that tube dock 114 of the second type is configured to provide three additional functionalities, it will be appreciated that in some implementations the tube dock 114 of the second type may be configured to provide less additional functionalities (e.g., only one cooling functionality) or more than three functionalities.

[0044] Fig. 3A illustrates an exemplary X-ray source that is formed by attaching the X-ray tube module 10 to the tube dock 114 of the second dock type. In this illustrated example, the exemplary tube dock 114 is configured to provide not only mains power and control electronics 124 to the X-ray tube module 10, but also the high voltage supply functionality, the additional cooling functionality, and the radiation shielding functionally. Such configuration may allow to use the X-ray tube module 10 in a high power mode and/or for longer scans.

[0045] Fig. 3B illustrates an exemplary cooling system 128 for the X-ray source shown in Fig. 3A. As shown in Fig. 3B, the exemplary cooling system 128 comprises a conduit 130 configured to guide the coolant proximate to the X-ray tube 10. The conduit 130 may have a coil shape to increase the contact surface between the X-ray tube module 10 and the coolant. As shown in Fig. 3B, the tube dock 114 may have an electrical connection 132 configured to electrically connect the tube dock 114 to mains power. The tube dock 114 may have a cooling interface 134 with an inlet 134a to receive the coolant from an external reservoir (not shown) holding a volume of coolant, and an outlet 134b to return the coolant passing through the cooling system 128 to the external reservoir.

[0046] Turning back to Fig. 1, the exemplary tube dock 116 of a third dock type may be configured with at least two X-ray tube interfaces to use two or more X-ray tube modules 10 at the same time. In the illustrated example, the tube dock 116 of the third dock type comprises a first X-ray tube interface 120a and a second X-ray tube interface 120b. The tube dock 116 may comprise control electronics 124 configured to control the operation of two or more connected X-ray tube modules. The tube dock 116 may further comprise a high voltage generator 126 configured to supply the two or more connected X-ray tube modules with a required high voltage. Although not shown, the tube dock 116 of the third dock type may alternatively or additionally comprise a cooling system configured to direct a flow of coolant proximate to the two or more connected X-ray tube modules so that the coolant removes at least some heat therefrom, and/or a radiation shielding arrangement configured to shield the two or more connected X-ray tube modules.

[0047] Fig. 4 illustrates an exemplary X-ray source that are formed by connecting the tube dock 116 of the third type to two or more X-ray tube modules. In the illustrated example, the foci of the two X-ray tube modules 10a and 10b are located at a relatively large distance to irradiate different body parts of a subject. The two X-ray fan beams may be partially overlapping as in Fig. 4 but still be detected by one large detector 30. Such configuration may be used to cover a wider Field of View (FOV). It will be appreciated that in some implementations the tube dock 116 may be configured to be connected to two X-ray tube modules with foci positioned at a relatively smaller distance than in Fig. 4 to have largely overlapping beams to provide some depth resolution like in tomosynthesis. In other words, the X-ray source shown in Fig. 4 may be configured to either cover a wider FOV or to provide some depth resolution like in tomosynthesis. For both applications, the irradiation may be time-interleaved so that any detected radiation may be associated with the correct X-ray tube module.

[0048] Fig. 5 illustrates a further example of the modular X-ray source system 100. In the illustrated example, the modular X-ray source system 100 comprises a plurality of X-ray tube modules of at least two different tube types selectively attachable to the at least one of the plurality tube docks 110, such as the tube dock 112, the tube dock 114, and the tube dock 116 shown in Fig. 5. Each tube type has at least one different tube characteristic. Examples of the at least one different tube char-

acteristic may include, but are not limited to, a different tube material, a different focal spot size, a different focal spot location, a different anode angle, a different power capability, and a different number of filaments of the cathode. In this way, it is possible to select one X-ray tube module from the plurality X-ray tube modules with a desired X-ray tube characteristic according to a particular application and attach this selected X-ray tube module to one of the plurality of tube docks 110. To facilitate the exchange of X-ray tube modules, the plurality of tube docks may comprise at least one tube dock with a tube alignment guide that is configured to permit free axial movement of the at least one X-ray tube module while restricting at least one of lateral movement and angular movement of the at least one X-ray tube module. In this way, it is possible to allow simple replacement of the X-ray tube module by non-expert for maintenance and adaption of the modular X-ray system via selection of the types of X-ray tube module.

[0049] Fig. 6 illustrates an exemplary X-ray source arrangement 140 comprising two or more of the plurality of tube docks arranged in a predetermined geometry, such as a linear array of tube docks. Each tube dock is attached to one or more X-ray tube modules. In this illustrated example, the X-ray source arrangement 140 comprises three tube docks including a first tube dock 112 of the first dock type, a second tube dock 114 of the second dock type, and a third tube dock 112 of the first dock type. Three X-ray tube modules 10a, 10b, and 10c are attached to these tube docks respectively. In some implementations, these X-ray tube modules 10a, 10b, and 10c may be X-ray tube modules having similar tube characteristics. In some implementations, these X-ray tube modules 10a, 10b, and 10c may be X-ray tube modules having different tube characteristics. For example, the X-ray tube module 10b may have a different anode material to generate X-rays with a different spectrum. The X-ray source arrangement 140 may be used to generate X-rays with a larger FOV. Additionally, each tube dock and X-ray tube module may be selected to generate different X-rays at different positions to meet the requirement of a special application. While Fig. 6 may show a limited number of tube docks in the X-ray source arrangement 140 by way of example, it will be appreciated that the X-ray source arrangement 140 may comprise more tube docks arranged in any predetermined geometry.

[0050] Fig. 7 illustrates a flowchart describing a method 200 of using the modular X-ray source system disclosed herein for generating X-ray radiation for an X-ray system.

At block 210, i.e., step a), the method 200 comprises the step of providing at least one X-ray tube module, such as the X-ray tube module 10 shown in Fig. 1.

[0051] At block 220, i.e., step b), the method 200 further comprises the step of providing at least one tube dock, such as one of the plurality of tube docks shown in Fig. 1.

[0052] At block 230, i.e., step c), the method 200 further comprises the step of attaching the at least one X-ray tube module to the at least one tube dock for X-ray generation. Some exemplary X-ray sources formed by attaching the at least one X-ray tube module to the at least one tube dock are shown in Fig. 2, Fig. 3A, Fig. 3B, and Fig. 4.

[0053] In some implementations, there may be a plurality of X-ray tube modules available, e.g., the X-ray tube modules 10a, 10b, and 10c shown in Fig. 5. At block 212, the method 200 may further comprise the step of providing a plurality of X-ray tube modules having different tube characteristics. At block 214, the method 200 may further comprise the step of selecting one X-ray tube module from the plurality of X-ray tube modules based on a performance requirement demanded by the X-ray system. At block 230, the selected X-ray tube module is attached to the at least one tube dock for X-ray generation.

[0054] In some implementations, step b) may further comprise the following steps. At block 222, the method 200 may further comprise the step of providing a plurality of tube docks of different dock types, each dock type providing at least one different functionality. At block 224, the method may further comprise the step of selecting one tube dock from the plurality of tube docks based on a performance requirement demanded by the X-ray system. At block 230, the at least one X-ray tube module is attached to the selected tube dock for X-ray generation.

[0055] It has to be noted that embodiments of the invention are described with reference to different subject matters. In particular, some embodiments are described with reference to method type claims whereas other embodiments are described with reference to the device type claims. However, a person skilled in the art will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters is considered to be disclosed with this application. However, all features can be combined providing synergetic effects that are more than the simple summation of the features.

[0056] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing a claimed invention, from a study of the drawings, the disclosure, and the dependent claims.

[0057] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are re-cited in mutually different dependent claims does

not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. A modular X-ray source system (100), comprising:

- at least one X-ray tube module (10) comprising an X-ray generating arrangement including a cathode and an anode, a vacuum housing enclosing the X-ray generating arrangement in an enclosure, and a dock interface; and
- a plurality of tube docks (110) of at least two different dock types, each dock type being configured to provide at least one different functionality, selectively attachable to the dock interface of the at least one X-ray tube module for operating the at least one X-ray tube module.

2. The modular X-ray source system according to claim 1,
wherein the at least one different functionality comprises a heat management functionality to provide thermal management for the at least one X-ray tube module.

3. The modular X-ray source system according to claim 2,
wherein the plurality of tube docks comprises at least one tube dock with a cooling arrangement configured to provide passive cooling of the at least one X-ray tube module, and/or a cooling system (128) configured to direct a flow of coolant proximate to the at least one X-ray tube module so that the coolant removes at least some heat therefrom.

4. The modular X-ray source system according any one of the preceding claims,
wherein at least one different functionality comprises a radiation shielding functionality to shield the at least one X-ray tube module.

5. The modular X-ray source system according to claim 4,
wherein the plurality of tube docks comprises at least one tube dock with a radiation shielding arrangement (130).

6. The modular X-ray source system according any one of the preceding claims,
wherein at least one different functionality comprises a high voltage supply functionality for supplying a high voltage to the at least one X-ray tube module.

7. The modular X-ray source system according to claim 6,
wherein the plurality of tube docks comprises at least one tube dock with a high voltage generator (126) configured to supply the at least one X-ray tube module with a required high voltage, and/or a high voltage generator interface configured to be electrically connectable to an external high voltage generator that is configured to supply the at least one X-ray tube module with a required high voltage.

8. The modular X-ray source system according to any one of the preceding claims,
wherein the plurality of tube docks comprises at least one tube dock with a tube alignment guide that is configured to permit free axial movement of the at least one X-ray tube module while restricting at least one of lateral movement and angular movement of the at least one X-ray tube module.

9. The modular X-ray source system according to any one of the preceding claims,
wherein the plurality of tube docks comprises at least one tube dock configured to be attachable to two or more X-ray tube modules.

10. The modular X-ray source system according to any one of the preceding claims,
wherein the at least one X-ray tube module comprises a plurality of X-ray tube modules (10a, 10b, 10c) of at least two different tube types, each tube type having at least one different tube characteristic, selectively attachable to the at least one of the plurality tube docks.

11. The modular X-ray source system according to claim 10,
wherein the at least one different tube characteristic comprises one or more of:

- a different tube material;
- a different focal spot size;
- a different focal spot location;
- a different anode angle;
- a different power capability; and
- a different number of filaments of the cathode.

12. The modular X-ray source system according to any one of the preceding claims, further comprising

- an X-ray source arrangement comprising two or more of the plurality of tube docks arranged in a predetermined geometry, each tube dock being attached to one or more X-ray tube modules.

13. A method (200) of using the modular X-ray source system according to any one of the preceding claims for generating X-ray radiation for an X-ray system, the method comprising:

a) providing (210) at least one X-ray tube module;
b) providing (220) at least one tube dock; and
c) attaching (230) the at least one X-ray tube module to the at least one tube dock for X-ray generation.

14. The method according to claim 13,

wherein step a) further comprises:

- providing a plurality of X-ray tube modules having different tube characteristics; and
- selecting one X-ray tube module from the plurality of X-ray tube modules based on a performance requirement demanded by the X-ray system; and

wherein step c) further comprises:

- attaching the selected X-ray tube module to the at least one tube dock for X-ray generation.

15. The method according to claim 13 or 14,

wherein step b) further comprises:

- providing a plurality of tube docks of different dock types, each dock type providing at least one different functionality; and
- selecting one tube dock from the plurality of tube docks based on a performance requirement demanded by the X-ray system; and

wherein step c) further comprises:

- attaching the at least one X-ray tube module to the selected tube dock for X-ray generation.

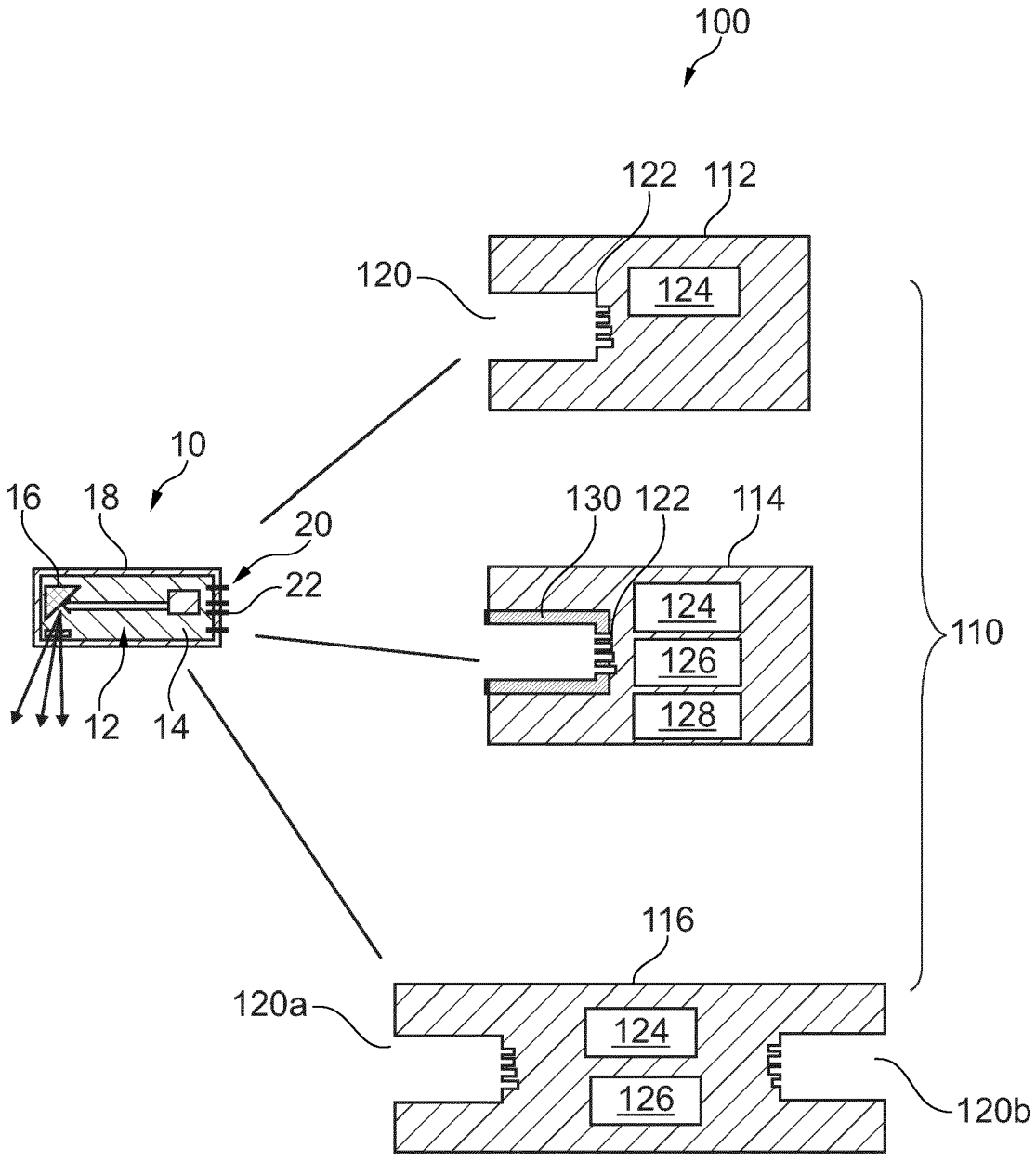
100
122
112
120
124
10
16
18
20
22
130
122
114
124
126
128
110
12
14
116
120a
124
126
120b

Fig. 1

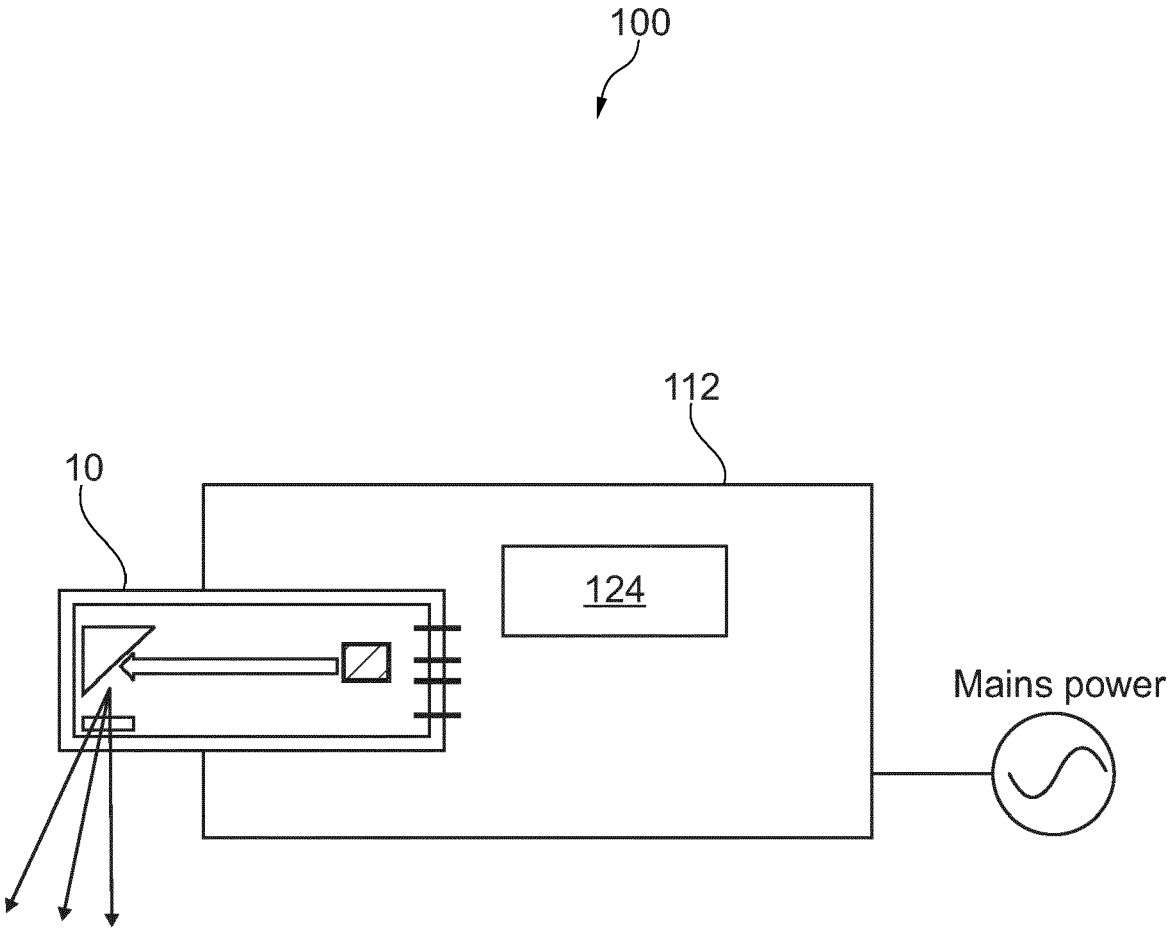

Fig. 2

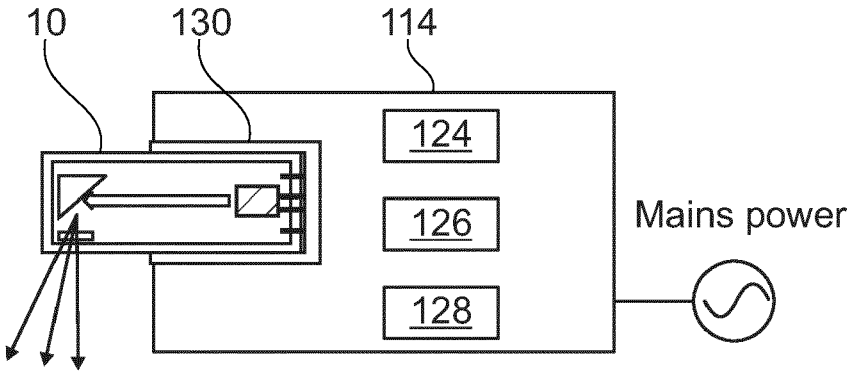
10
130
114
124
126
128
Mains power

Fig. 3A

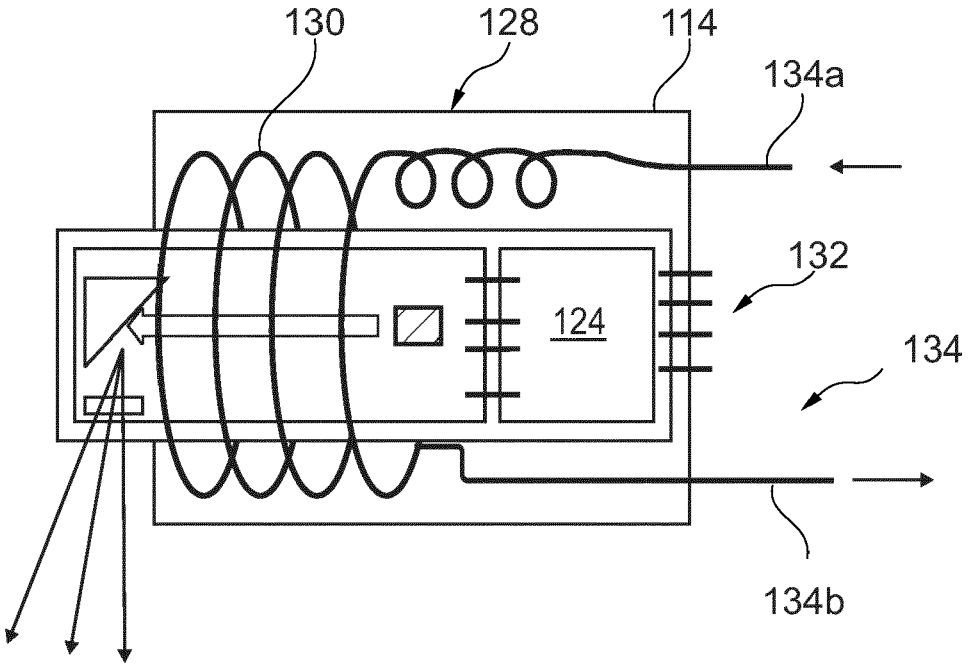
130
128
114
134a
132
124
134
134b

Fig. 3B

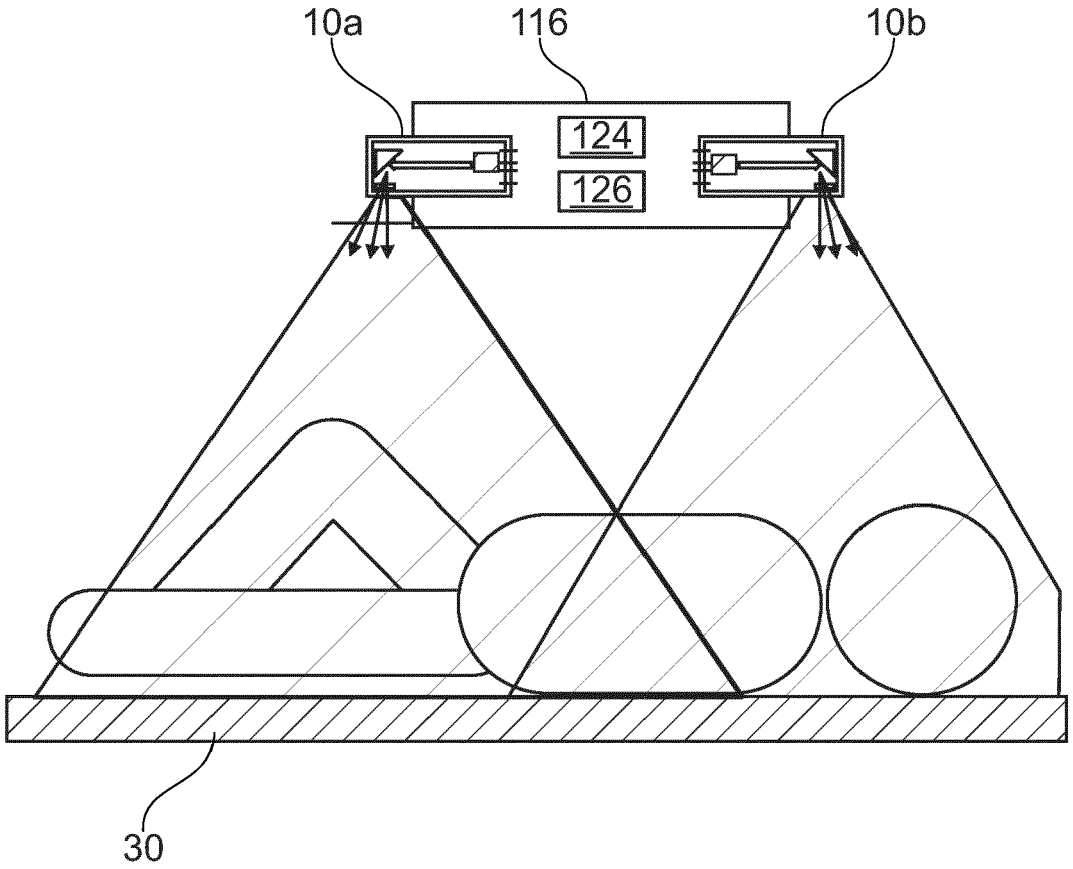

Fig. 4

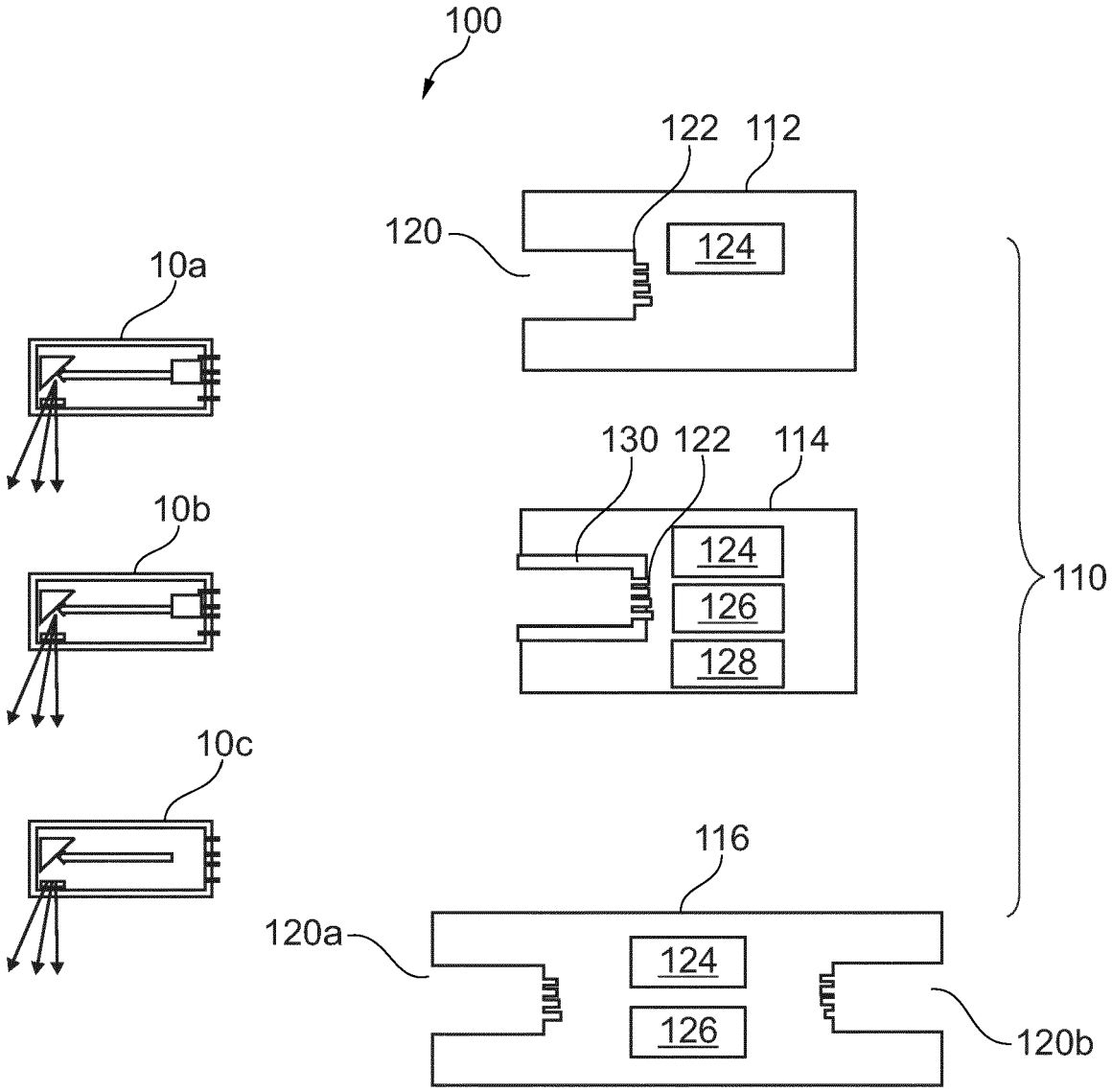
100
122
112
120
124
10a
130
122
114
10b
124
126
128
110
10c
116
120a
124
126
120b

Fig. 5

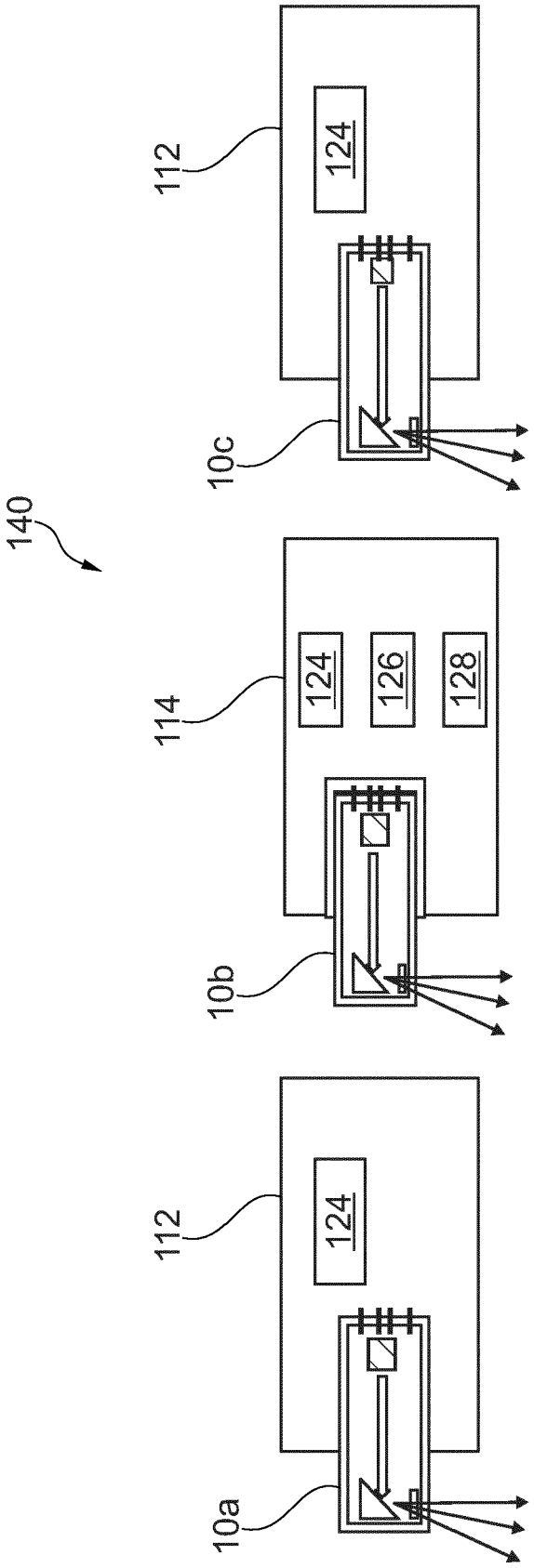

Fig. 6

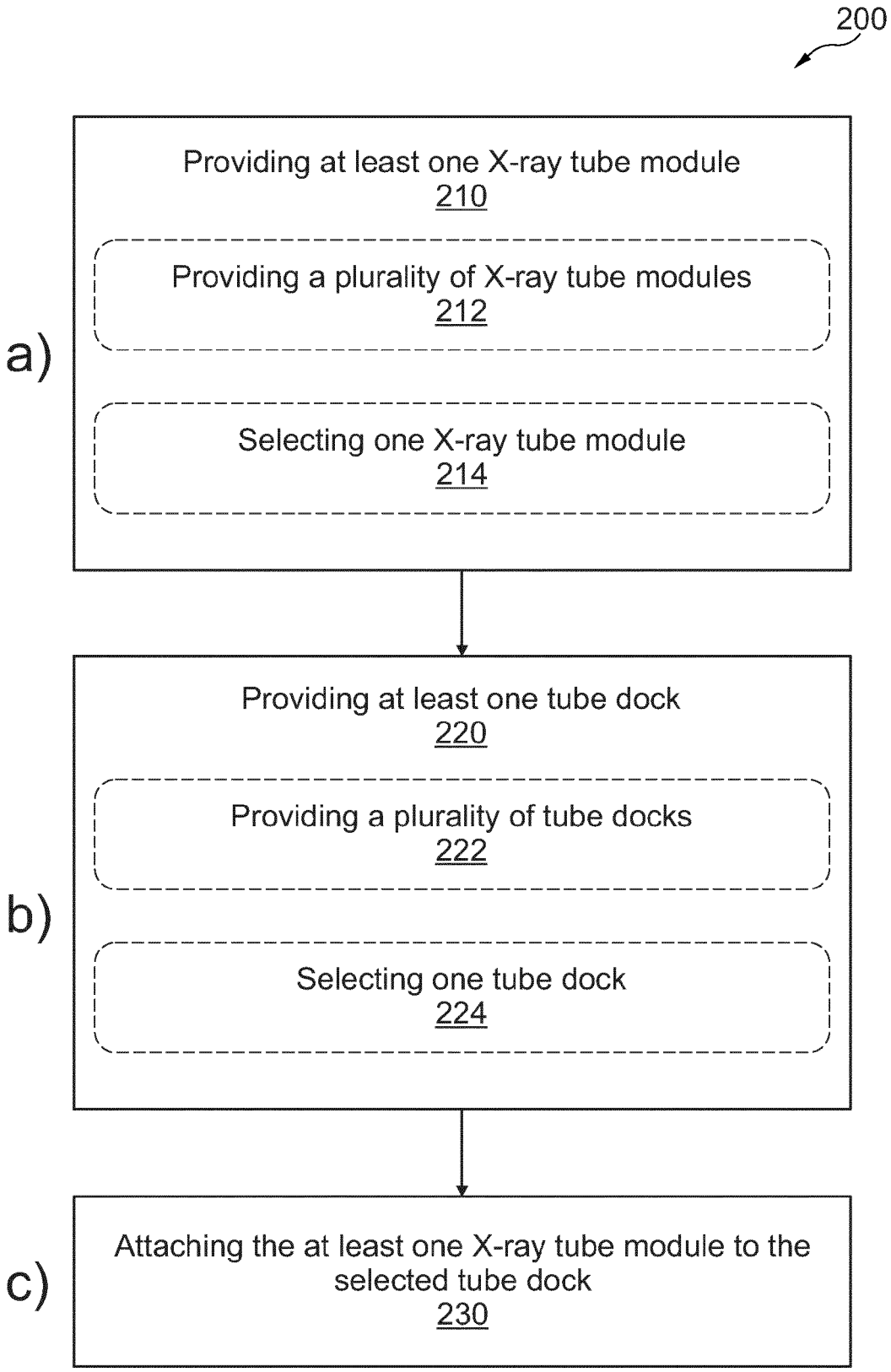
200
a)
Providing at least one X-ray tube module
210
Providing a plurality of X-ray tube modules
212
Selecting one X-ray tube module
214
b)
Providing at least one tube dock
220
Providing a plurality of tube docks
222
Selecting one tube dock
224
c)
Attaching the at least one X-ray tube module to the selected tube dock
230

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 24 15 0986

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 5 313 512 A (TANAKA SHIGERU [JP]) 17 May 1994 (1994-05-17) * see fig. 8 and the description thereof * -----	1-3,13, 15	INV. H05G1/02 H05G1/10 H01J35/16

TECHNICAL FIELDS SEARCHED (IPC)

H05G
H01J

~~The present search report has been drawn up for all claims~~

1

Place of search	Date of completion of the search	Examiner
The Hague	3 June 2024	Angloher, Godehard

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
.....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

Europäisches Patentamt
European Patent Office
Office européen des brevets

Application Number
EP 24 15 0986

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-3, 13, 15

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 24 15 0986

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-3, 13, 15

A modular X-ray source system according to claim 1 / A method according to claim 13 of using the modular X-ray source system according to e.g. claim 1
additional subject-matter common to claims 2 and 3:
the at least one different functionality comprises a heat management functionality to provide thermal management for the at least one X-ray tube module;

1.1. claim: 15

see the additional features of the respective claim/s;

---

2. claims: 4, 5

A modular X-ray source system according to e.g. claim 1;
special technical features common to claims 4 and 5:
at least one different functionality comprises a radiation shielding functionality to shield the at least one X-ray tube module;

---

3. claims: 6, 7

A modular X-ray source system according to e.g. claim 1;
special technical features common to claims 6 and 7:
at least one different functionality comprises a high voltage supply functionality for supplying a high voltage to the at least one X-ray tube module;

---

4. claim: 8

A modular X-ray source system according to e.g. claim 1;
special technical features of claim 8:
the plurality of tube docks comprises at least one tube dock with a tube alignment guide that is configured to permit free axial movement of the at least one X-ray tube module while restricting at least one of lateral movement and angular movement of the at least one X-ray tube module;

---

5. claims: 9, 12

A modular X-ray source system according to e.g. claim 1;
special technical features of claim 9:
the plurality of tube docks comprises at least one tube dock configured to be attachable to two or more X-ray tube modules;

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 24 15 0986

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

special technical features of claim 12:
an X-ray source arrangement comprising two or more of the plurality of tube docks arranged in a predetermined geometry, each tube dock being attached to one or more X-ray tube modules;

---

6. claims: 10, 11, 14

A modular X-ray source system according to e.g. claim 1 / A method according to claim 13 of using the modular X-ray source system according to e.g. claim 1
special technical features common to claims 10 and 11:
the at least one X-ray tube module comprises a plurality of X-ray tube modules (10a, 10b, 10c) of at least two different tube types, each tube type having at least one different tube characteristic, selectively attachable to the at least one of the plurality tube docks;
special technical features of claim 14:
step a) further comprises:
- providing a plurality of X-ray tube modules having different tube characteristics; and
- selecting one X-ray tube module from the plurality of X-ray tube modules based on a performance requirement demanded by the X-ray system; and
wherein step c) further comprises:
- attaching the selected X-ray tube module to the at least one tube dock for X-ray generation.

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 24 15 0986

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-06-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5313512 A	17-05-1994	JP 3080634 B2	28-08-2000
		JP H03261054 A	20-11-1991
		US 5313512 A	17-05-1994