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(54) Title: A UNIT AND EQUIPMENT FOR RADIOTHERAPEUTIC PRECLINICAL STUDIES

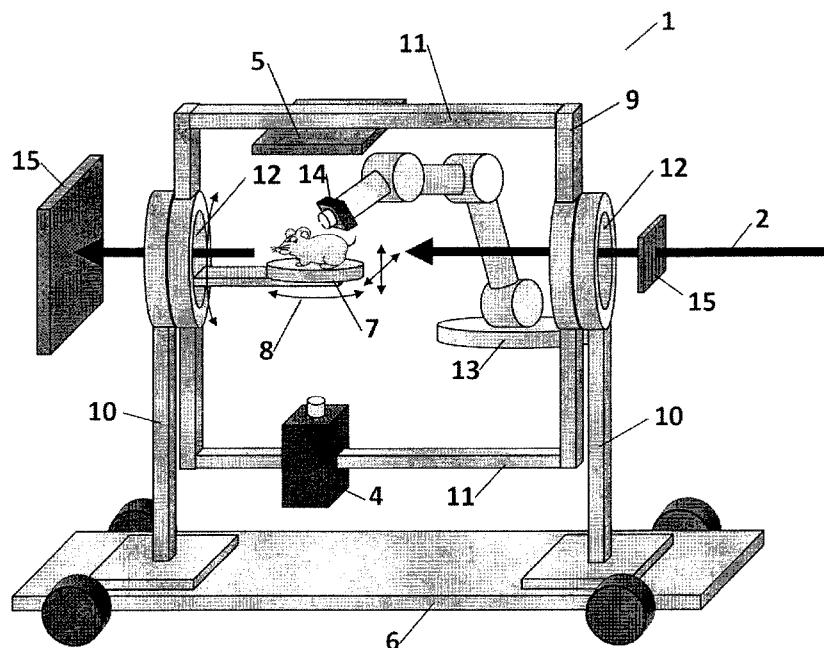


Fig. 1

(57) Abstract: The unit (1) according to the invention is intended for the irradiation of the object by the therapeutic beam (2) of particles from the external source (3) along with the concurrent CT scanning of the object using at least one scanning pair consisting of the source (4) of the scanning ionizing radiation and of the imaging detector (5) arranged on the opposite side. The unit is intended for radiotherapeutic preclinical studies on animals inside the existing radiotherapy vaults. The unit comprises the mobile platform (6) equipped with the adjustable table (7) and with a load-bearing means supporting a scanning pair with movable installation as to the adjustable table (7), where the load-bearing means, scanning pair and adjustable table (7) delimit the free working space (8) for unshielded travel of the therapeutic beam (2) of particles through the unit (1).



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A Unit and Equipment for Radiotherapeutic Preclinical Studies

Field of the Invention

The invention concerns a unit and equipment for combined irradiation by a therapeutic particle beam and simultaneous irradiation by other ionizing radiation (e.g. photons) combined with the CT imaging. The purposes are preclinical studies on animals using ionising radiation beams. The unit is placed inside an existing radiotherapy vault for human clinical radiotherapy by the therapeutic beam of particles.

Background of the Invention

The so-called radiotherapy has been used recently in particular for the treatment of oncological diseases. A method of treatment where cancer tissue is destroyed by targeted irradiation by a therapeutic beam of ionizing radiation is concerned. The incident beam of the therapeutic ionizing radiation releases energy into the irradiated tissue that leads to irreversible damage to the tissue cells resulting in their destruction. Among the known kinds of therapeutic ionizing radiation are in particular photon radiation, e.g. x-ray radiation and a therapeutic beam of particles, such as protons or neutrons.

Another application of ionizing radiation is the acquisition of a three-dimensional model of the internal structure of the irradiated object by computed tomography. By the detection of the therapeutic beam of ionizing radiation passing through the irradiated object in different directions and by the analysis of changes in this beam due to transmission through the object, and also, for example, by the detection of e.g. fluorescent ionizing radiation or scattered ionizing radiation or back-scattered ionizing radiation, it is possible to acquire a three-dimensional model of the internal structure of the irradiated object or at least part of it. The aforementioned method utilizing computed tomography can be referred to as the CT scanning process.

Within the framework of radiotherapy both methods mentioned above are customarily used. The tissue intended for the applications of therapeutic ionizing radiation is localized and subsequently treated by radiotherapy. It is advantageous to perform both steps at the same time.

An example of such a solution is the invention disclosed in the WO 2007060242 A1 document. The invention deals with the equipment for the application of radiotherapy using a therapeutic particle beam and parallel imaging based on x-rays and computing tomography. Another similar solution is for example the invention disclosed in the DE 102006000837 A1 patent application. Both inventions mentioned above present combined irradiation for therapeutic purposes and computed tomography.

A drawback of photon radiation is that it affects also healthy tissue found along the path of its propagation. This drawback is partially compensated by therapeutic beams of particles that are able to release most of their energy at the end of their propagation path, the so-called Bragg peak. On the other hand, a disadvantage of therapeutic particle beams rests in the fact that currently there is not enough clinically ascertained information on the efficacy of the therapeutic beams of particles of certain types for specific kinds of tumour tissues. Although there has been intensive research, the progress is limited by the number of laboratories and other sites allowing radiotherapeutic preclinical studies on animals to be performed.

Currently there is a very limited number of sites allowing radiotherapeutic preclinical studies using therapeutic particle beams, namely because of the fact that particle accelerators, whose purchase and operating costs are very high, are needed for the acquisition of the therapeutic particle beam. In a majority of cases, the clinical centres being built are equipped with radiotherapy vaults for clinical radiotherapy that earn money needed for the payment of operating and purchase costs by the treatment of patients. Therefore, such clinical centres are naturally interested in booking most of the operating time of such radiotherapy vaults for clinical treatment leaving only a minimum time for radiotherapeutic preclinical studies.

Preclinical studies are usually performed on laboratory animals, such as rats and mice requiring equipment suitable for study-specific experiments on small irradiated objects. However, the existing space and equipment for radiotherapy vaults of clinical centres have been adapted for the treatment of large irradiated objects, and therefore it is necessary to adapt the existing equipment and space of the radiotherapy vault of the clinical centres for the preclinical studies. Such adaptations would however reduce the capacity available for clinical treatment and are undesirable, which brings back again the urging problem of insufficient space for the performance of radiotherapeutic preclinical studies.

The task of the invention is the development of a unit and equipment for combined irradiation for preclinical studies that would be utilizable within the framework of the radiotherapy vaults of the existing clinical centres without requiring any radical adaptation of the radiotherapy vault of the clinical centre or change in the present clinical equipment. Moreover, the system allows all measurements and irradiation to be done without necessity of transferring the animal. This greatly improves the precision of measurement and irradiation.

Summary of the Invention

The set goal has been achieved by the development of a unit for the performance of radiotherapeutic preclinical studies on animals based on the following invention.

The unit is intended for the irradiation of the object by a therapeutic particle beam, from an external source and parallel CT scanning of the object using at least one scanning pair, in particular for radiotherapeutic preclinical studies on animals. The scanning pair consists of the source of ionizing radiation and the imaging detector of ionizing radiation arranged on the opposite side.

The essence of the invention rests in the fact that the unit comprises a mobile platform equipped with an adjustable table supporting the irradiated object. In addition, the mobile platform is equipped with at least one load-bearing means that supports at least one scanning pair arranged in a movable manner as to the adjustable table. In addition, the load-bearing

means, scanning pair and adjustable table delimit free working space for unshielded travel of the therapeutic particle beam through the unit.

The mobile platform allows an easy transport of the unit to its destination and also easy cleaning of the unit for the destination restoration. The mobile platform is equipped with instruments necessary for the execution of radiotherapeutic preclinical studies on animals, such as an adjustable table to place the irradiated object into the path of the therapeutic particle beam and load-bearing means to support the scanning pair that is movable as to the adjustable table to perform the scanning of the irradiated object from various directions within the framework of the CT scanning process. At the same time, the free working space, through which the therapeutic particle beam travels in an unshielded manner from the outlet of the external source of the therapeutic particle beam, is delimited. The therapeutic particle beam passes through the irradiated object placed on the adjustable table. Such arrangement is advantageous as it is not necessary to adjust the external source in any radical manner. All other equipment needed for radiotherapeutic preclinical studies is supplied to the site within the framework of the unit or cleaned from the site without limiting the function of the external source.

In a preferred embodiment of the unit according to the invention, the load-bearing means consists of a rotating support frame fixed using axial bearings between two columns protruding from the mobile platform. The rotating support column ensures the movability as to the adjustable table and the rotating support frame has at least two arms supporting the scanning pair allowing the arrangement of the scanning pair elements on the opposite sides. The columns and arms of the rotating support frame also delimit the free working space, and the inner rings of the axial bearings are arranged at the inlet of the therapeutic particle beam into the free working space and at the outlet of the therapeutic particle beam from the free working space not to shield the therapeutic particle beam travelling through the load-bearing means of the unit.

In a preferred embodiment of the unit according to the invention, the scanning pair on the arms of the rotating support frame is adjustable. Thanks to adjusting, the scanning pair can be adapted to various types of irradiated objects placed on the adjustable table.

In another preferred embodiment of the unit according to the invention, the load-bearing means consists of at least one robotic arm. The robotic arm is very well controllable and also very precise when moving as programmed. Robotic arms can work in an environment exposed to ionizing radiation.

In a preferred embodiment of the unit according to the invention, the mobile platform is equipped with at least one adjustable source of ionizing radiation. By adding a source of ionizing radiation it is possible to perform combined irradiation including two types of therapeutic irradiation and one type of scanning irradiation at the same time. Preferably, the source of therapeutic ionizing radiation is attached to the robotic arm itself to allow its location as to the irradiated tissue to be detected.

In a preferred embodiment of the unit according to the invention, the unit is equipped with at least one imaging detector of the therapeutic particle beam, preferably equipped with two imaging detectors of the therapeutic particle beam, where the first imaging detector is arranged at the inlet of the therapeutic particle beam into the delimited free working space and the other imaging detector is arranged at the outlet of the therapeutic particle beam from the free working space. By the monitoring of the shape and properties of the therapeutic particle beam prior to entering the irradiated tissue and by the subsequent monitoring of changes and consequences after the irradiation of the irradiated tissue, data for better understanding of the effect of the therapeutic particle beam on the irradiated tissue can be acquired. Preferably, the imaging detector is arranged at the rotating support frame or column or robotic arm itself.

The invention also includes equipment for the performance of radiotherapeutic preclinical studies on animals inside radiotherapy vaults for clinical radiotherapeutic irradiation.

The equipment includes radiotherapy vaults with the outlet of the external source of the therapeutic particle beam installed in the inner space of the vault.

The essence of the invention rests in the fact that the equipment comprises a unit designed according to any of the patent claims. The unit is placed in the inner space of the radiotherapy vault and in the equipment, it is oriented for unshielded passage of the therapeutic particle beam from the outlet of the therapeutic particle beam of the external source through the free working space delimited by the unit.

The equipment allows radiotherapeutic preclinical studies to be performed on animals using the existing radiotherapy vaults for the clinical radiotherapy of patients. Thanks to the equipment it is possible to perform preclinical studies without interventions in the equipment of radiotherapy vaults at the time when no therapy is delivered, and it is possible to restore the operation of the radiotherapy vault in a very short time to resume the treatment of patients.

Among the advantages of the invention is the possibility to perform preclinical studies to a large extent without having to build new radiotherapy vaults for preclinical studies requiring considerable expenses. The use of the existing radiotherapy vaults for the treatment of patients is temporary and does not interfere with the functionality for the treatment of patients. The purchase costs of the invention are many times lower compared to those related to the construction of laboratories equipped with custom radiotherapy vaults for radiotherapeutic preclinical studies.

Explanation of Drawings

The present invention will be explained in detail by means of the following figures where:

Fig. 1 illustrates the unit with a load-bearing means consisting of a rotating support frame,

Fig. 2 illustrates the unit with a load-bearing means consisting of robotic arms,

Fig. 3 illustrates a simplified image of the equipment for radiotherapeutic preclinical studies.

An Example of the Invention Embodiment

It shall be understood that the specific cases of the invention embodiments described and depicted below are provided for illustration only and do not limit the invention to the examples provided here. Those skilled in the art will find or, based on routine experiment, will be able to provide a greater or lesser number of equivalents to the specific embodiments of the invention which are described here. Also, such equivalents will be included in the scope of the following claims.

Fig. 1 provides an illustration of the unit 1 for irradiation of the object by the therapeutic beam 2 of particles from the external source 3 not included in the figure along with the concurrent CT scanning of the object using at least one scanning pair consisting of the source 4 of the scanning ionizing radiation and the imaging detector 5 of ionizing radiation arranged on the opposite side. The therapeutic beam 2 of particles can be, for example, a beam of protons that were accelerated in the particle accelerator forming the external source 3 not provided in the figure. A person skilled in the field of radiotherapeutic irradiation will be able to describe a whole group of therapeutic beams 2, including a group of external sources 3 for the creating thereof. The source 4 of scanning ionizing radiation comprises a powered x-ray tube for the emission of the scanning x-rays; the imaging detector 5 can be, for example, a semiconductor hybrid detector. As in the case of the therapeutic beam 2 of particles, a person skilled in the field of the CT scanning process will be able to create by routine work additional variants of the scanning pair, functionally equivalent to the disclosure provided in the patent application. The object intended for irradiation is in particular a laboratory animal.

The unit 1 comprises the mobile platform 6 for its easy transport to/from the radiotherapy vault 16. The mobile platform 6 is comprised of a load-bearing structure equipped with travelling wheels and a brake to fix the unit 1 on the spot. The mobile platform 6 supports the adjustable table 7 allowing the object to be positioned with six degrees of freedom. In addition, the mobile platform 6 includes a load-bearing means formed by the rotating support frame 9 illustrated in Fig. 1. The drive of the rotating frame 9 is provided in the form

of electric motor not shown in the figure. The load-bearing means, scanning pair and adjustable table 7 limit the free working space 8 for unshielded travel of the therapeutic beam 2 of particles through the unit. The rotating support frame 9 is fixed using axial bearings between two columns 10 protruding from the mobile platform 6. The axial bearings have a wide inner ring 12 for unshielded travel of the therapeutic beam 2 of particles into the working space 8 towards the object and further. In the illustrated example of the embodiment, the rotating support frame 9 has two beams 11, where one of the beams 11 includes the source 4 of scanning ionizing radiation installed in an adjustable manner and the other beam 11 includes the imaging detector 5 installed in an adjustable manner. The rotating support frame 9 allows the CT scanning process to be executed by the scanning pair. In addition, Fig. 1 illustrates the robotic arm 13 equipped with the source 14 of therapeutic ionizing radiation. The robotic arm 13 can be adjusted in a manner allowing therapeutic irradiation of the object from two sources 3, 14 of therapeutic radiation to be executed at the same time, including CT scanning during which the rotating support frame 9 is moving along only a part of its trajectory. Figure 1 provides an illustration of a simplified scheme, however, the robotic arm 13 is also supported by the mobile platform 6. In addition, the mobile platform 6 supports the imaging detectors 15 arranged along the trajectory of the therapeutic beam 2 of particles at the inlet and outlet of the therapeutic beam 2 to/from the free working space 8.

Fig. 2 provides an illustration of the embodiment of the unit 1 with the mobile platform 6 equipped with load-bearing means implemented only by the robotic arms 13. The illustrated robotic arms 13 support the scanning pair. The unit 1 in the embodiment of the invention not provided in the figure can have the robotic arms 13 equipped with the source 14 of therapeutic ionizing radiation, adjustable table 7, and also, for example, detectors 15. The detectors 15 can be also held by robotic arms 13 to allow changing positions of the detector 15 in respect to a particle beam 2 that is delivered from varying directions by a rotating gantry. The robotic arms 13 allow precise positioning in space.

Figure 3 illustrates a diagram of the radiotherapy vault 16 and the position of the unit 1 inside the radiotherapy vault 16. The therapeutic beam 2 of particles from the external source 3 is

supplied to the radiotherapy vault **16**. The interior of the radiotherapy vault **16**, such as the table **17** for patients, does not need to be removed from the radiotherapy vault **16**.

Industrial Applicability

The unit and equipment for radiotherapeutic preclinical studies according to the invention will be used in scientific research and medicine when performing radiobiology preclinical studies on animals.

Overview of the positions

- 1 irradiation unit
- 2 therapeutic particle beam
- 3 external source
- 4 scanning ionizing radiation source
- 5 imaging detector
- 6 mobile platform
- 7 adjustable table
- 8 free working space
- 9 rotating support frame
- 10 vertical column
- 11 rotating support frame arm
- 12 inner ring of the axial bearing
- 13 robotic arm
- 14 therapeutic ionizing radiation source
- 15 imaging detector
- 16 radiotherapy vault
- 17 table for patients

CLAIMS

1. The unit (1) for the irradiation of the object by the therapeutic beam (2) of particles from the external source (3) and simultaneous CT scanning of the object using at least one scanning pair consisting of the source (4) of scanning ionizing radiation and of the imaging detector (5) of ionizing radiation arranged on the opposite side, in particular for radiotherapeutic preclinical studies on animals **characterized in that** it consists of the mobile platform (6) equipped with the adjustable table (7) to support the irradiated object and equipped with at least one load-bearing means supporting at least one scanning pair installed in a movable manner as to the adjustable table (7), where the load-bearing means, scanning pair and adjustable table (7) delimit the free working space (8) for unshielded travel of the therapeutic beam (2) of particles through the unit (1).
2. The unit according to claim 1 **characterized in that** the load-bearing means consists of the rotating support frame (9) fixed using axial bearings between two columns (10) protruding from the mobile platform (6), where the rotating support frame (9) has at least two arms (11) to support the scanning pair, and where the columns (10) and arms (11) of the rotating support frame (9) delimit the free working space (8), and with the inner rings (12) of the axial bearings arranged at the inlet of the therapeutic beam (2) of particles to the delimited free working space (8) and at the outlet of the therapeutic beam (2) of particles from the free working space (8) for unshielded travel of the therapeutic beam (2) of particles through the load-bearing means.
3. The unit according to claim 3 **characterized in that** the scanning pair on the arms (11) of the rotating support frame (9) is adjustable.
4. The unit according to claim 1 **characterized in that** the load-bearing means consists of at least one robotic arm (13).

5. The unit according to any of claims 1 to 5 **characterized in that** the mobile platform (6) is equipped with at least one adjustable source (14) of therapeutic ionizing radiation.
6. The unit according to claim 5 **characterized in that** the source (14) of therapeutic ionizing radiation is arranged at the robotic arm (13) itself.
7. The unit according to any of claims 1 to 6 **characterized in that** it is equipped with at least one imaging detector (15) of the therapeutic beam (2) of particles.
8. The unit according to claim 7 **characterized in that** it is equipped with two imaging detectors (15) of the therapeutic beam (2) of particles, where the first imaging detector (15) is arranged at the inlet of the therapeutic beam (2) of particles into the delimited free working space (8) and the other imaging detector (15) is arranged at the outlet of the therapeutic beam (2) of particles from the free working space (8).
9. The unit according to claim 7 or 8 **characterized in that** the imaging detector (15) is arranged at the rotating support frame (9) or the column (10) or a robotic arm (13).
10. The equipment to conduct preclinical studies using ionising beams on animals inside radiotherapy vaults (16) for clinical radiotherapeutic irradiation of patients with the outlet of the external source (3) of the therapeutic beam (2) of particles installed in the inner space of the vaults **characterized in that** the equipment comprises the unit (1) designed according to any of patent claims 1 through 10 that is placed in the inner space of the radiotherapy vault (16), where the unit is arranged as to the outlet of the external source (3) for unshielded travel of the therapeutic beam (2) of particles through the free working space (8) delimited by the unit (1).

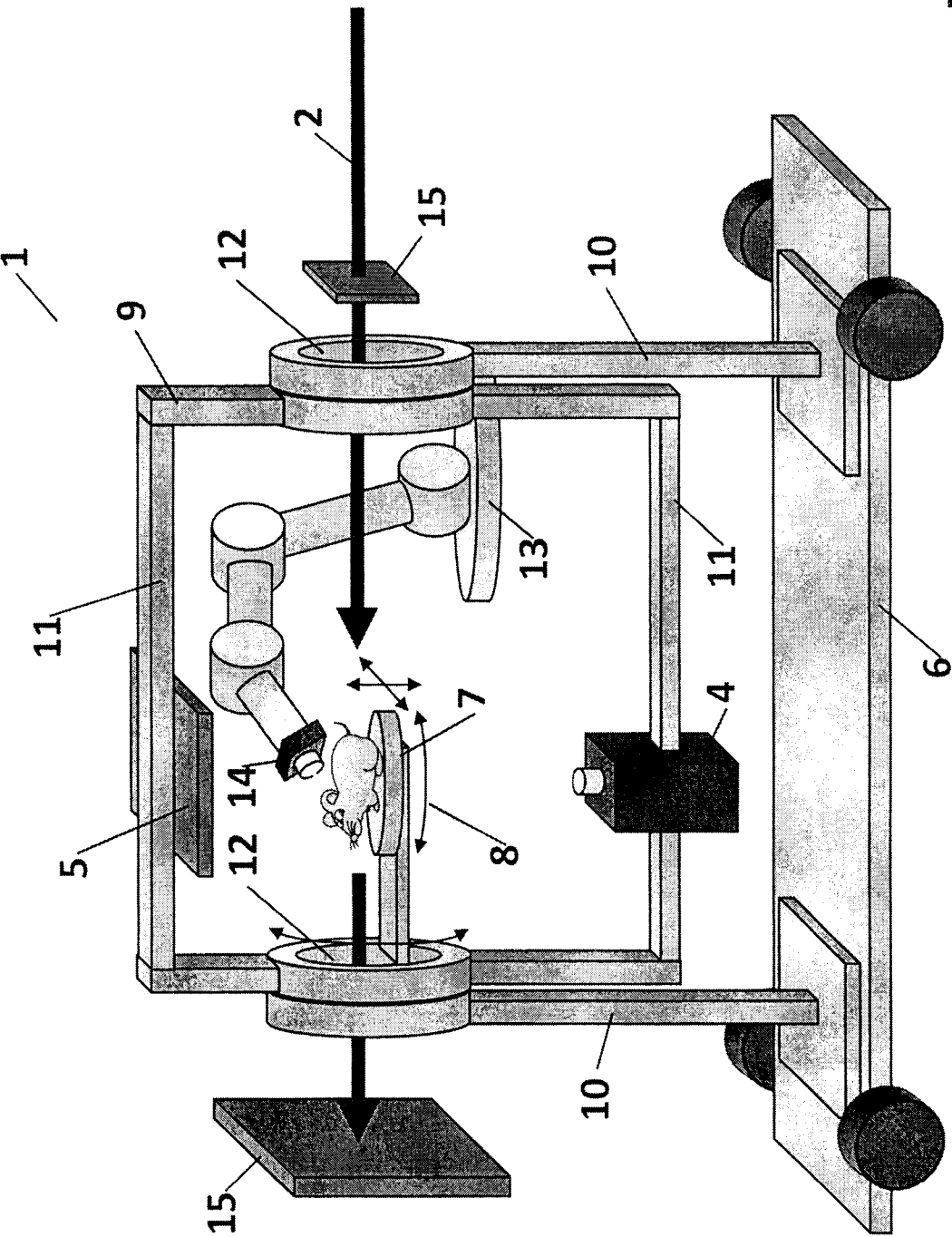
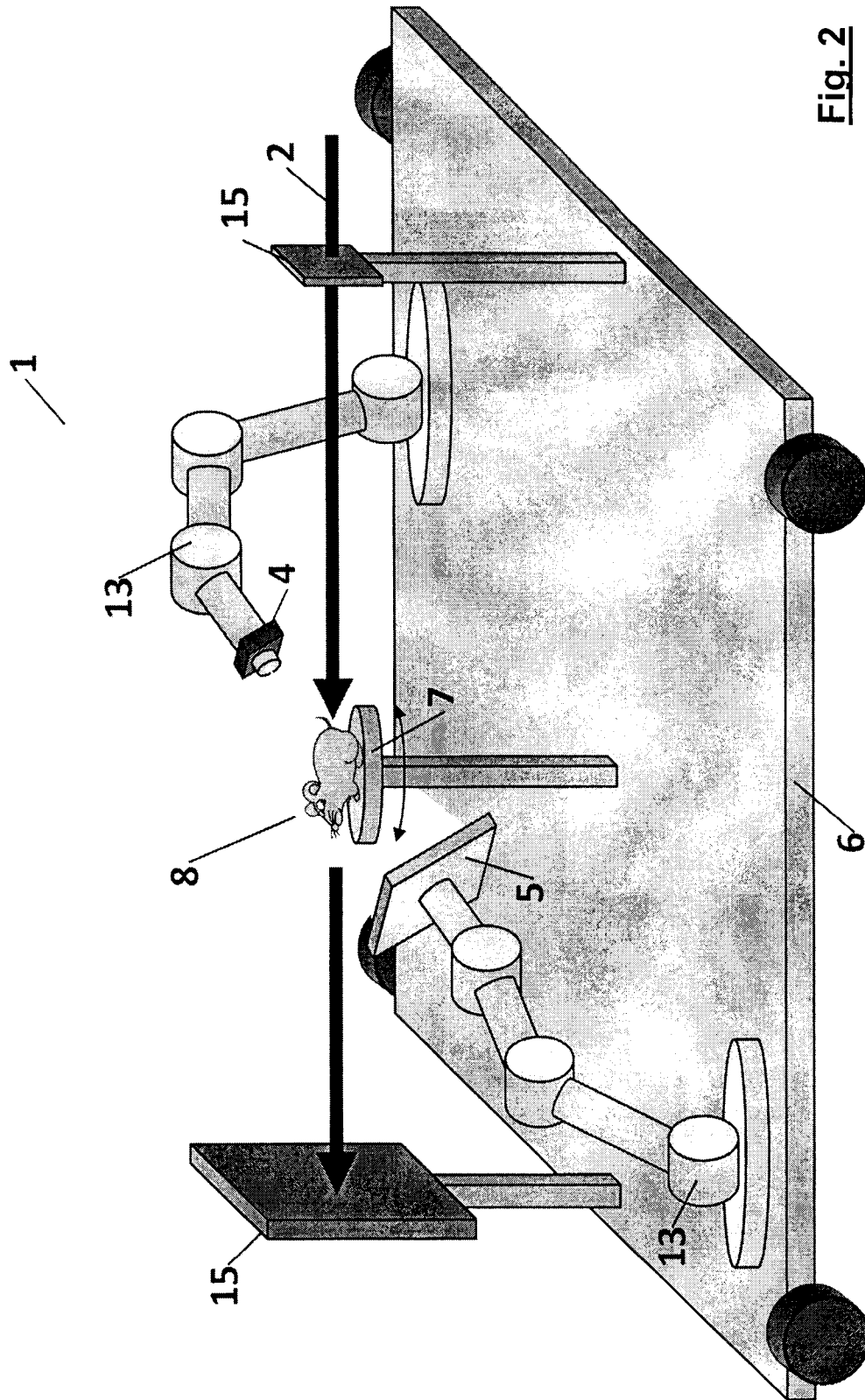


Fig. 1



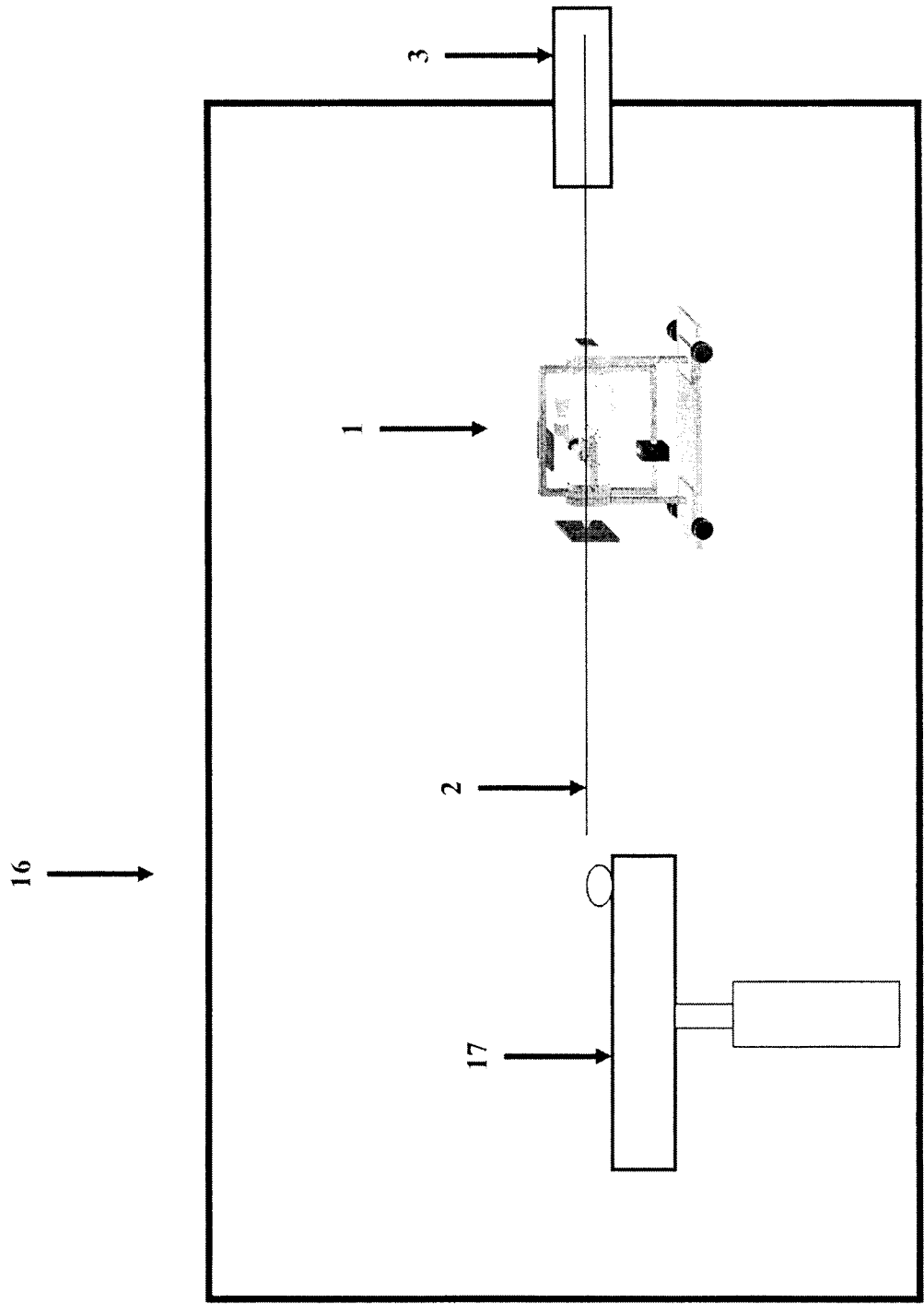


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER

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ADD. A61B6/00 A61N5/10

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)

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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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 3 106 093 A1 (DEUTSCHMANN HEINRICH [AT]) 21 December 2016 (2016-12-21) abstract paragraphs [0006], [0032] - [0047] figures 1,2,5 -----	1,3,4, 7-10 5,6
X	US 2016/338656 A1 (GREGERSON EUGENE A [US]) 24 November 2016 (2016-11-24) abstract paragraphs [0008], [0033] - [0041] figures 1,3 -----	1-3
X	DE 10 2014 207568 A1 (SIEMENS AG [DE]) 22 October 2015 (2015-10-22) abstract paragraphs [0012], [0049] - [0057] figures 3,5 ----- -/--	1,2



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No

PCT/CZ2018/050002

C(Continuation). 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

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