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United States Patent	12390174
Kind Code	B2
Date of Patent	August 19, 2025
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Detector module, detector, and medical device

Abstract

Provide are a detector module, a detector, and a medical device. The detector module includes a plurality of detection sub-modules at least partially arranged in a stepped manner in a first direction. Each of the plurality of detection sub-modules includes a plurality of photoelectric conversion units arranged at intervals in a second direction intersecting with the first direction. One of two adjacent detection sub-modules is located at a higher step as a first detection sub-module, and the other one is located at a lower step and as a second detection sub-module. A first gap is formed between the plurality of photoelectric conversion units of the first detection sub-module. A second gap is formed between the plurality of photoelectric conversion units of the second detection sub-module. A width of the first gap in the second direction is smaller than a width of the second gap in the second direction.

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Appl. No.: **18/299030**

Filed: **April 11, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20230240626 A1	Aug. 03, 2023

Foreign Application Priority Data

CN	202211317211.9	Oct. 26, 2022

Publication Classification

Int. Cl.: **A61B6/03** (20060101); **G01T1/164** (20060101); **G01T1/20** (20060101); **G01T1/24** (20060101)

U.S. Cl.:

CPC **A61B6/032** (20130101); **G01T1/1644** (20130101); **G01T1/2006** (20130101); **G01T1/243** (20130101); **G01T1/247** (20130101);

Field of Classification Search

CPC: A61B (6/032); G01T (1/1644); G01T (1/2006)

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Primary Examiner: Maupin; Hugh

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This application claims priority to Chinese Patent Application No. 202211317211.9 filed on Oct. 26, 2022, the entire disclosure of which is incorporated herein by reference.

FIELD

(2) The present disclosure relates to the field of medical device technologies, and in particular, to a detector module, a detector, and a medical device.

BACKGROUND

(3) With continuous development of medical levels, more and more medical devices are used to assist medical diagnosis or therapy. For example, a Computed Tomography (CT) device is used to detect human diseases. The CT device can detect an X-ray passing through a human body through a CT detector, and convert a received optical signal into an electrical signal.

(4) A detector usually includes a plurality of detector modules in a direction Z. The plurality of detector modules is arranged in a stepped manner and has an arc-shaped outer contour in a direction X. In this case, widths of gaps between the detector modules in different steps in the direction X are different from each other. Further, as the number of steps of the detector increases, ununiformily irregular gaps with different widths would be formed, which is unfavorable for image reconstruction, thereby affecting a diagnosis result.

SUMMARY

(5) The present disclosure aims to at least solve one of the technical problems in the related art.

(6) To this end, a first aspect of the present disclosure provides a detector module.

(7) A second aspect of the present disclosure provides a detector.

(8) A third aspect of the present disclosure provides a medical device.

(9) In view of this, according to the first aspect of embodiments of the present disclosure, a detector module is provided. The detector module includes a plurality of detection sub-modules at least partially arranged in a stepped manner in a first direction. Each of the plurality of detection sub-modules includes a plurality of photoelectric conversion units arranged at intervals in a second direction intersecting with the first direction. One of two adjacent detection sub-modules of the plurality of detection sub-modules is located at a higher step as a first detection sub-module, and the other one of the two adjacent detection sub-modules is located at a lower step and as a second detection sub-module. A first gap is formed between the plurality of photoelectric conversion units of the first detection sub-module. A second gap is formed between the plurality of photoelectric conversion units of the second detection sub-module. A width of the first gap in the second direction is smaller than a width of the second gap in the second direction.

(10) In some embodiments of the present disclosure, each gap between the plurality of photoelectric conversion units of the first detection sub-module is the first gap; and/or each gap between the plurality of photoelectric conversion units of the second detection sub-module is the second gap.

(11) In some embodiments of the present disclosure, a third gap is further formed between the plurality of photoelectric conversion units of the first detection sub-module, the third gap and the first gap being arranged in the second direction, and a width of the third gap in the second direction being different from the width of the first gap in the second direction; and/or a fourth gap is further present between the plurality of photoelectric conversion units of the second detection sub-module, the fourth gap and the second gap being arranged in the second direction, and a width of the fourth gap in the second direction being different from the width of the second gap in the second direction.

(12) In some embodiments of the present disclosure, in the second direction, the width of the third gap is smaller than the width of the first gap, and the width of the fourth gap is smaller than the width of the second gap.

(13) In some embodiments of the present disclosure, the width of the third gap in the second direction is equal to the width of the fourth gap in the second direction.

(14) In some embodiments of the present disclosure, an odd number of gaps are formed between the plurality of photoelectric conversion units of the first detection sub-module, the first gap being alternately arranged with the third gap, and a head gap and a tail gap of the odd number of gaps are each the third gap. An odd number of gaps are present between the plurality of photoelectric conversion units of the second detection sub-module, the second gap being alternately arranged with the fourth gap, and a head gap and a tail gap of the odd number of gaps are each the fourth

gap.
(15) In some embodiments of the present disclosure, the plurality of photoelectric conversion units of the first detection sub-module has a same width in the second direction; and/or the plurality of photoelectric conversion units of the second detection sub-module has a same width in the second direction.
(16) In some embodiments of the present disclosure, the plurality of photoelectric conversion units of the first detection sub-module has a same width as the plurality of photoelectric conversion units of the second detection sub-module in the second direction.
(17) In some embodiments of the present disclosure, the detector module further includes a support, a substrate disposed on the support; and an analog-to-digital converter connected to the photoelectric conversion units. The photoelectric conversion units and the analog-to-digital converter are disposed on the substrate and arranged in the first direction. The substrate of the first detection sub-module is superposed on the analog-to-digital converter of the second detection sub-module.
(18) According to a second aspect of embodiments of the present disclosure, a detector is provided. The detector includes a plurality of detector modules. Each of the plurality of detector modules is the detector module as described in any one of the embodiments of the present disclosure. The plurality of detector modules is arranged in the second direction, and detection sub-modules of the plurality of detector modules at a same step are adjacent to each other.
(19) In some embodiments of the present disclosure, a fifth gap is formed between adjacent first detection sub-modules. A sixth gap is formed between adjacent second detection sub-modules. In the second direction, a width of the fifth gap is equal to the width of the first gap, and a width of the sixth gap is equal to the width of the second gap.
(20) In some embodiments of the present disclosure, the detection sub-modules at the same step has surfaces tangent to circles with a same radius.
(21) According to a third aspect of embodiments of the present disclosure, a medical device is provided. The medical device includes a housing defining a scanning chamber, and a detection assembly disposed in the housing. The detection assembly includes the detector as described in any one of the embodiments of the present disclosure. The first direction is an extending direction of the scanning chamber.
(22) Compared with the related art, the present disclosure at least includes the following beneficial effects. The detector module according to the embodiments of the present disclosure includes the plurality of detection sub-modules. In operation, the radiation source can emit rays towards a scanned object. The radiation source may emit fan-shaped or conical ray beams, and each ray beam includes several rays. The radiation source can project the ray beams from its focus to the scanned object. The plurality of detection sub-modules of the detector module can detect a ray attenuated by the scanned object, convert an optical signal of the received ray into an electrical signal, and transmit the electrical signal to an upper computer for imaging. With the detector module according to the embodiments of the present disclosure, the plurality of detection sub-modules is at least partially arranged in the stepped manner in the first direction, and each of the plurality of detection sub-modules includes the plurality of photoelectric conversion units arranged at intervals in the second direction. With this arrangement, the detector module can include two or more layers of the detection sub-module arranged in the stepped manner. In this way, the gap between two adjacent detection sub-modules in the first direction can be reduced or eliminated as much as possible, to obtain more complete scanning data of a scanned part, thereby improving accuracy of a diagnosis result. Further, in a case where the detector includes the plurality of detector modules arranged in the second direction, a gap between the detector modules is difficult to be eliminated. In the detector module according to the embodiments of the present disclosure, in the case where the detector includes the plurality of detector modules, the first detection sub-module of the detector is arranged closer to the radiation source, and the second detection sub-module is arranged away from

the radiation source relative to the first detection sub-module. Thus, the second detection sub-module away from the radiation source has a longer length (larger diameter) than the first detection sub-module closer to the radiation source. Thus, a larger gap is formed between two adjacent second detection sub-modules of the plurality of second detection sub-modules away from the radiation source. In addition, each of the plurality of detection sub-modules includes the plurality of photoelectric conversion units arranged at intervals in the second direction. One of two adjacent sub-modules of the plurality of detection sub-modules is located at the higher step as the first detection sub-module, and the other one of the two adjacent sub-modules is located at the lower step as the second detection sub-module. The first gap is formed between the plurality of photoelectric conversion units of the first detection sub-module. The second gap is formed between the plurality of photoelectric conversion units of the second detection sub-module. The width of the first gap in the second direction is smaller than the width of the second gap in the second direction. Therefore, the larger gap between two adjacent detection sub-modules in a same step can be shared into the detection sub-module. Thus, on one hand, the gaps between the detection sub-modules in the same step and the gaps in the detection sub-modules can be relatively uniformly arranged in the second direction, and on the other hand, a gap difference between detector sub-modules in adjacent steps can be reduced, which is beneficial to subsequent image reconstruction and improves diagnosis accuracy.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) Various other advantages and benefits will become apparent to those of ordinary skill in the art by reading the detailed description of preferred embodiments below. The accompanying drawings are merely for illustrating the preferred embodiments, rather than limiting the present disclosure. Moreover, throughout the accompanying drawings, same components/parts are denoted by same reference numerals. In the accompanying drawings:

(2) FIG. **1** is a schematic structural view of a detector module according to an embodiment of the present disclosure;

(3) FIG. **2** is a schematic structural view of a detector module according to a first embodiment of the present disclosure at a viewing angle;

(4) FIG. **3** is a schematic structural view of a detector module according to a second embodiment of the present disclosure at a viewing angle;

(5) FIG. **4** is a schematic structural view of a detector module according to a third embodiment of the present disclosure at a viewing angle:

(6) FIG. **5** is a schematic structural view of a first detection sub-module of a detector module according to an embodiment of the present disclosure;

(7) FIG. **6** is a schematic structural view of a second detection sub-module of a detector module according to an embodiment of the present disclosure;

(8) FIG. **7** is a schematic structural view of a detection sub-module of a detector module according to an embodiment of the present disclosure;

(9) FIG. **8** is a schematic structural view of a photoelectric conversion unit of a detection sub-module of a detector module according to an embodiment of the present disclosure;

(10) FIG. **9** is a schematic structural view of a detector according to an embodiment of the present disclosure; and

(11) FIG. **10** is a schematic structural view of a medical device according to an embodiment of the present disclosure;

(12) Here, a correspondence between reference numerals and components in FIG. **1** to FIG. **10** is: **100** detector module; **110** detection sub-module, **120** support, **130** substrate, **140** analog-to-digital

converter, **150** scintillator array, **160** protection plate; **111** first detection sub-module, **112** second detection sub-module, **113** photoelectric conversion unit, **114** first gap, **115** second gap, **116** third gap, **117** fourth gap, **118** photodiode array; **200** detector; **210** fifth gap, **220** sixth gap; **310** housing, **320** radiation source, **330** scanning opening, **340** bearing bed, **350** examiner.

DETAILED DESCRIPTION

(13) The technical solutions of embodiments of the present disclosure will be described in detail below in combination with accompanying drawings and specific embodiments in order to better understand the above technical solutions. It should be understood that the embodiments of the present disclosure and specific features in the embodiments are detailed descriptions of the technical solutions of the embodiments of the present disclosure, rather than limiting the technical solutions of the present disclosure. The embodiments of the present disclosure or technical features in the embodiments can be combined to each other without contradiction.

(14) A detector usually includes a plurality of detector modules in a direction Z. The plurality of detector modules is arranged in a stepped manner and has an arc-shaped outer contour in a direction X. In this case, widths of gaps between detector modules in different steps in the direction X are different from each other. Further, as the number of steps of the detector increases, nonuniform irregular gaps with different widths would be formed. The inventor of the present disclosure found that a large gap between adjacent detector modules and inner and outer gaps of the detector module are not uniform, both of which are unfavorable for subsequent image reconstruction.

(15) As illustrated in FIG. **1** to FIG. **8**, according to a first aspect of embodiments of the present disclosure, a detector module **100** is provided. The detector module **100** includes a plurality of detection sub-modules **110** at least partially arranged in a stepped manner in a first direction. Each of the plurality of detection sub-modules **110** includes a plurality of photoelectric conversion units **113** arranged at intervals in a second direction. One of two adjacent sub-modules of the plurality of detection sub-modules **110** is located at a higher step as a first detection sub-module **111**, and the other one of the two adjacent sub-modules is located at a lower step as a second detection sub-module **112**. A first gap **114** is formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**. A second gap **115** is formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. A width of the first gap **114** in the second direction is smaller width than a width of the second gap **115** in the second direction. The first direction intersects with the second direction.

(16) The detector module **100** according to the embodiments of the present disclosure includes the plurality of detection sub-modules **110**. In operation, a radiation source **320** can emit rays towards a scanned object. The radiation source **320** may emit fan-shaped or conical ray beams, and each ray beam includes several rays. The radiation source **320** can project the ray beams from its focus to the scanned object. The plurality of detection sub-modules **110** of the detector module **100** is configured to detect a ray attenuated by the scanned object, convert an optical signal of the received ray into an electrical signal, and transmit the electrical signal to an upper computer for imaging.

(17) With the detector module **100** according to the embodiments of the present disclosure, the plurality of detection sub-modules **110** is at least partially arranged in the stepped manner in the first direction, and each of the plurality of detection sub-modules **110** includes the plurality of photoelectric conversion units **113** arranged at intervals in the second direction. With this arrangement, the detector module **100** can include two or more layers of the detection sub-module **110** arranged in the stepped manner. In this way, the gap between two adjacent detection sub-modules **110** in the first direction can be reduced or eliminated as much as possible, to obtain more complete scanning data of a scanned part, thereby improving accuracy of a diagnosis result.

(18) Further, in a case where the detector **200** includes the plurality of detector modules **100** arranged in the second direction, a gap between the detector modules **100** is difficult to be

eliminated. In the detector module **100** according to the embodiments of the present disclosure, in the case where the detector **200** includes the plurality of detector modules **100**, the first detection sub-module **111** of the detector **200** is arranged closer to the radiation source **320**, and the second detection sub-module **112** is arranged away from the radiation source **320** relative to the first detection sub-module **111**. Thus, the second detection sub-module **112** away from the radiation source **320** has a longer length than the first detection sub-module **111** closer to the radiation source **320**. That is, a radius of a step where the first detection sub-module is located is smaller than a radius of a step where the second detector sub-module is located, so that a larger gap is formed between two adjacent second detection sub-modules **112** of the plurality of second detection sub-modules **112** away from the radiation source **320**. In addition, each of the plurality of detection sub-modules **110** includes the plurality of photoelectric conversion units **113** arranged at intervals in the second direction. One of two adjacent sub-modules of the plurality of detection sub-modules **110** is located at the higher step as the first detection sub-module **111**, and the other one of the two adjacent sub-modules is located at the lower step as the second detection sub-module **112**. The first gap **114** is formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**. The second gap **115** is formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. The width of the first gap **114** in the second direction is smaller than the width of the second gap **115** in the second direction. Therefore, the larger gap between two adjacent detection sub-modules in a same step can be shared into the detection sub-module **110**. Thus, on one hand, the gaps between the detection sub-modules **110** in the same step and the gaps in the detection sub-modules can be relatively uniformly arranged in the second direction, and on the other hand, a gap difference between detector sub-modules in adjacent steps can be reduced, which is beneficial to subsequent image reconstruction and improves diagnosis accuracy.
(19) With the detector module **100** according to the embodiments of the present disclosure, the first gap **114** is formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**. The second gap **115** is formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. It should be understood that the first detection sub-module **111** may include at least two photoelectric conversion units **113**, and at least one gap may be formed between the plurality of photoelectric conversion units **113**. With the detector module **100** according to the embodiments of the present disclosure, the plurality of gaps in the first detection sub-module **111** includes the first gap. It should be noted that the first gap **114** may be one, two, or more gaps. Similarly, the second detection sub-module **112** may include at least two photoelectric conversion units **113**, and at least one gap may be formed between the at least two photoelectric conversion units **113**. In the detector module **100** according to the embodiments of the present disclosure, the plurality of gaps in the second detection sub-module **112** may include the second gap. It should be noted that the second gap **114** may be one, two, or more gaps.
(20) It should be understood that, as illustrated in FIG. **2** to FIG. **4** and FIG. **7**, the first direction is a direction Z, the second direction is a direction X. The direction Z may refer to a width direction of the detector, a feeding direction of a scanning bed, or an extending direction of a scanning chamber. The first direction is perpendicular to the second direction. A direction Y can be defined as a third direction, and may refer to a height direction of the detector module. The first direction, the second direction, and the third direction are perpendicular to each other.
(21) In a feasible implementation, each gap between the plurality of photoelectric conversion units **113** of the first detection sub-module **111** is the first gap **114**, and/or each gap between the plurality of photoelectric conversion units **113** of the second detection sub-module **112** is the second gap **115**.
(22) In this technical solution, an arrangement of the gaps in the first detection sub-module III is further provided. The plurality of photoelectric conversion units **113** is included in the first detection sub-module **111**. Therefore, a plurality of gaps can be formed between the plurality of

photoelectric conversion units **113**, and each of the plurality of gaps is the first gap **114**. That is, the gaps between the first detection sub-modules are equally distributed into the first detection sub-module. With this arrangement, production and processing of the first detection module are facilitated, which can reduce processing difficulty.

(23) In this technical solution, an arrangement of the gaps in the second detection sub-module **112** is further provided. The plurality of photoelectric conversion units **113** is included in the second detection sub-module **112**. Therefore, a plurality of gaps may be formed between the plurality of photoelectric conversion units **113**, and each of the plurality of gaps is the second gap **115**. That is, the gaps between the second detection sub-modules **112** are equally distributing into the first detection sub-module. With this arrangement, production and processing of the second detection module are facilitated, which can reduce the processing difficulty.

(24) As illustrated in FIG. **5** and FIG. **6**, in a feasible implementation, a third gap **116** is further formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**, the third gap **116** and the first gap **114** are arranged in the second direction, and a width of the third gap **116** in the second direction is different from the width of the first gap **114** in the second direction; and/or a fourth gap **117** is further formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**, the fourth gap **117** and the second gap **115** are arranged in the second direction, and a width of the fourth gap **117** in the second direction is different from the width of the second gap **115** in the second direction.

(25) In this technical solution, another arrangement of the gaps in the first detection sub-module **111** is further provided. The plurality of photoelectric conversion units **113** is included in the first detection sub-module **111**. Therefore, a plurality of gaps can be formed between the plurality of photoelectric conversion units **113**. Further, some of the plurality of gaps are the first gap **114**, and some of the plurality of gaps are the third gap **116**. Moreover, the third gap **116** has the different width from the first gap **114**. In this way, in a processing process of the detector module **100**, the gap between the two adjacent detection sub-modules **110** at the same step and the gaps in the detection sub-module can be relatively uniformly arranged in the second direction by only changing an arrangement position of the photoelectric conversion unit **113** in the middle of the detection sub-module **110**. Therefore, the gap difference between the detection sub-modules in different steps can be reduced even to zero.

(26) In this technical solution, another arrangement of the gaps in the second detection sub-module **112** is further provided. The plurality of photoelectric conversion units **113** is included in the second detection sub-module **112**. Therefore, a plurality of gaps can be formed between the plurality of photoelectric conversion units **113**. Further, some of the plurality of gaps are the second gap **115**, and some of the plurality of gaps are the fourth gap **117**. Moreover, the width of the fourth gap **117** is different from the width of the second gap **115**. In this way, in the processing process of the detector module **100**, the gap between the two adjacent detection sub-modules **110** at the same step and the gaps in the detection sub-module can be relatively uniformly arranged in the second direction by only changing the arrangement position of the photoelectric conversion unit **113** in the middle of the detection sub-module **110**. Therefore, the gap difference between the detection sub-modules in different steps can be reduced even to zero.

(27) As illustrated in FIG. **5** and FIG. **6**, in a feasible implementation, in the second direction, the width of the third gap **116** is smaller than the width of the first gap **114**, and the width of the fourth gap **117** is smaller than the width of the second gap **115**.

(28) In this technical solution, a width relationship between the third gap **116** and the first gap **114** and a width relationship between the fourth gap **117** and the second gap **115** are further provided. The width of the third gap **116** is smaller than the width of the first gap **114**. The width of the fourth gap **117** is smaller than the width of the second gap **115**. Each of the width of the third gap **116** and the width of the fourth gap **117** in the second direction can be understood as a basic width. Each of the width of the first gap **114** and the width of the second gap **115** in the second direction can be

understood as an adjusted width for adjusting the gap between the detection sub-modules. With this arrangement, the gap between different detection sub-modules **110** of the detector **200** at the same step in the second direction can be adjusted by the arrangement of some of the first gaps **114** and the arrangement of some of the second gaps **115**, which is beneficial to the image reconstruction and can improve the diagnosis accuracy.

(29) As illustrated in FIG. **5** and FIG. **6**, in a feasible implementation, the width of the third gap **116** is equal to the width of the fourth gap **117** in the second direction.

(30) In this technical solution, a width relationship between the third gap **116** and the fourth gap **117** is further provided. The width of the third gap **116** is equal to the width of the fourth gap **117**. Based on this, a difference between the first detection sub-module **111** and the second detection sub-module **112** becomes smaller, so that the difference between the first detection sub-module **111** and the second detection sub-module **112** is only in the difference between the first gap **114** and the second gap **115**. With this arrangement, the detection sub-modules **110** at different steps can be conveniently produced and processed, which can improve processing and assembly efficiency of the detector module.

(31) As illustrated in FIG. **5** and FIG. **6**, in a feasible implementation, an odd number of gaps are formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **11**. Further, the first gap **114** is alternately arranged with the third gap **116**, and a head gap and a tail gap of the odd number of gaps are each the third gap **116**. In addition, an odd number of gaps are formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. Further, the second gap **115** is alternately arranged with the fourth gap **117**, and a head gap and a tail gap of the odd number of gaps are each the fourth gaps **117**.

(32) In this technical solution, an arrangement of the first gaps **114** and the third gaps **116** is further provided in a case where both the first gap **14** and the third gap **116** are formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**. The first gap **114** is alternately arranged with the third gap **116**, and a head gap and a tail gap among the first gap **14** and the third gap **116** are each the third gaps **116**. In the detector **200**, the gap between the first detection sub-modules **111** and the first gap **114**, or adjacent first gaps **114** are spaced apart from each other by the third gap **116**. With this arrangement, the gaps between the detection sub-modules at the same step and the gaps in the detection sub-module are relatively uniform and regularly arranged, which is beneficial to the image reconstruction.

(33) In this technical solution, an arrangement of the second gaps **115** and the fourth gaps **117** is further provided in a case of both the second gap **115** and the fourth gap **117** are formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. The second gap **115** is alternately arranged with the fourth gap **117**, and a head gap and a tail gap among the second gap **115** and the fourth gap **117** are each the third gap the fourth gaps **117** are arranged at head and tail positions. In the detector **200**, the gap between the second detection sub-module **112** and the second gap **115**, or adjacent second gaps **115** are spaced apart from each other by the fourth gap **117**. With this arrangement, the gaps between the detection sub-modules at the same step and the gaps in the detection sub-module are relatively uniform and regularly arranged, which is beneficial to the image reconstruction.

(34) As illustrated in FIG. **5** and FIG. **6**, in a feasible implementation, the plurality of photoelectric conversion units **113** of the first detection sub-module **111** has a same width in the second direction; and/or the plurality of photoelectric conversion units **113** of the second detection sub-module **112** has a same width in the second direction.

(35) In this technical solution, a relationship between the plurality of photoelectric conversion units **113** in each first detection sub-module **111** is further provided, in which the plurality of photoelectric conversion units **113** of the first detection sub-module **111** has the same width. In this way, the plurality of photoelectric conversion units **113** has a same structure, thereby facilitating production and assembly of the first detection sub-module **111**.

(36) In this technical solution, a relationship between the plurality of photoelectric conversion units **113** in each second detection sub-module **112** is further provided, in which the plurality of photoelectric conversion units **113** of the second detection sub-module **112** has the same width. In this way, the plurality of photoelectric conversion units **113** has a same structure, thereby facilitating production and assembly of the second detection sub-module **112**.
(37) In a feasible implementation, the width of each of the plurality of photoelectric conversion units **113** of the first detection sub-module **111** is the same as the width of each of the plurality of photoelectric conversion units **113** of the second detection sub-module **112** in the second direction.
(38) In this technical solution, parameter information of the photoelectric conversion unit **113** between the first detection sub-module **111** and the second detection sub-module **112** is further provided. The width of each of the plurality of photoelectric conversion units **113** of the first detection sub-module **111** is the same as the width of each of the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. With this arrangement, a difference between the detection sub-modules **110** in different steps can be further reduced, so that the detection sub-modules **110** in the different steps can use the same photoelectric conversion unit **113**. Thus, it is possible to reduce production cost and improve detection precision.
(39) As illustrated in FIG. **1**, FIG. **7**, and FIG. **8**, in a feasible implementation, the detector module **100** further includes a support **120**, a substrate **130**, and an analog-to-digital converter **140**. The analog-to-digital converter **140** is connected to the photoelectric conversion unit **113**. The photoelectric conversion unit **113** and the analog-to-digital converter **140** are disposed on the substrate **130** and arranged in the first direction. The substrate **130** is disposed on the support **120**. The substrate **130** of the first detection sub-module **111** is superposed on the analog-to-digital converter **140** of the second detection sub-module **112**.
(40) In this technical solution, a structural composition of the detector module **100** is further provided. The detection module may include the support **120**, the substrate **130**, and the analog-to-digital converter **140**. The support **120** can support and fix the plurality of detection sub-modules **110**. The substrate **130** can provide mounting positions for the photoelectric conversion unit **113** and the analog-to-digital converter **140**. The analog-to-digital converter **140** is configured to transmit a signal.
(41) In some examples, the photoelectric conversion unit **113** may include a photodiode array **118**, and the detector module **100** may further include a scintillator array **150** disposed on the photodiode array **118**. The scintillator array **150** is configured to receive the rays attenuated by the scanned object and convert the rays into visible light. The photodiode array **118** is configured to obtain an electrical signal based on the visible light.
(42) It should be understood that the substrate **130** serves as a carrier for carrying the scintillator array **150** and the photodiode array **118** and transmitting an electrical signal generated by the photodiode array **118** to the analog-to-digital converter **140** by using a CMOS integrated circuit technology. A traditional circuit technology for connecting lines and circuit boards is replaced with the CMOS integrated circuit technology, which can shorten a signal transmission distance, reduces interference factors during signal transmission, and facilitate image quality improvement. Meanwhile, such analog-to-digital converter **140** can be biased at low cost.
(43) As illustrated in FIG. **1**, in some examples, the detector module **100** further includes a protection plate **160** disposed on a side of each of the plurality of detection sub-modules **110** away from the support **120**.
(44) In this technical solution, the protection plate **160** is configured to protect the analog-to-digital converter **140** of the detection sub-module **110** from the damage on the analog-to-digital converter **140** due to the rays.
(45) In some examples, the protection plate **160** may be a tungsten sheet. It should be understood that other metal sheets having a protective function are suitable in the present disclosure.
(46) As illustrated in FIG. **9**, according to a second aspect of the embodiments of the present

disclosure, a detector **200** is provided. The detector includes a plurality of detector modules according to any one of the above technical solutions. The plurality of detector modules **100** is arranged in the second direction. Detection sub-modules **110** of the plurality of detector modules **100** at the same step are adjacent to each other.

(47) The detector **200** according to the embodiments of the present disclosure includes the plurality of detector modules **100** according to any one of the above technical solutions. Therefore, the detector **200** has all beneficial effects of the detector module **100** as described in the above technical solutions.

(48) The detector **200** according to the embodiments of the present disclosure includes the plurality of detector modules **100** arranged in the second direction. In addition, the first detection sub-module **111** of each of the plurality of detector modules **100** at a higher step is the first detection sub-module **111**, and the detection sub-module **111** of each of the plurality of detector modules **100** at a lower step is the second detection sub-module **112**. The first gaps **114** are formed between the plurality of photoelectric conversion units **113** of the first detection sub-module **111**. The second gaps **115** are formed between the plurality of photoelectric conversion units **113** of the second detection sub-module **112**. The width of each first gap **114** is smaller than the width of each second gap **115** in the second direction. Thus, the larger gap between the two adjacent detection sub-modules can be shared into the detection sub-module **110**. Therefore, on one hand, the gaps between the detection sub-modules **110** in the same step and the gaps in the detection sub-modules can be relatively uniformly arranged in the second direction, and on the other hand, a gap difference between detector sub-modules in adjacent steps can be reduced, which is beneficial to subsequent image reconstruction and improves the diagnosis accuracy.

(49) In a feasible implementation, a fifth gap **210** is formed between adjacent first detection sub-modules **111**, and a sixth gap **220** is formed between adjacent second detection sub-modules **112**. In the second direction, the fifth gap **210** has an equal width to the first gap **114**, and the sixth gap **220** has an equal width to the second gap **115**.

(50) In this technical solution, value ranges of the fifth gap **210** and the sixth gap **220** are further provided. The fifth gap **210** has the equal width to the first gap **114**, and the sixth gap **220** has the equal width to the second gap **115**. With this arrangement, it is possible for the gap between two adjacent detection sub-modules in the detector **200** at the same step in the second direction to be same as at least some of the gaps in the detection sub-module. Further, it is also possible for the sixth gap **220** in adjacent steps to approach the fifth gap **210**. With this arrangement, it is beneficial to relative uniform arrangement of the gaps in the detector **200**, and the gaps include the gap between the detection sub-modules and the gap in the detection sub-module. Therefore, it is possible to facilitate the image reconstruction and improve the diagnosis accuracy.

(51) In a feasible implementation, each of the detection sub-modules **110** at the same step has a surface tangent to a circle with a same radius.

(52) In this technical solution, an arrangement of the detection sub-modules **110** at the same step is further provided, in which each of the detection sub-modules **110** at the same step has the surface tangent to the circle with the same radius. Therefore, the fan-shaped or conical ray beams emitted from the radiation source **320** can be better adapted, which enables the rays to substantially vertically be incident onto a surface of the photoelectric conversion unit **113**. Thus, the detection precision is improved.

(53) According to a third aspect of the embodiments of the present disclosure, a medical device is provided. The medical device includes a housing **310** and a detection assembly disposed in the housing **310**. A scanning chamber is formed within the housing **310**. The detection assembly includes the detector **200** according to any one of the above technical solutions. The first direction is an extending direction of the scanning chamber.

(54) It should be understood that the medical device according to the embodiments of the present disclosure includes the detector **200** according to any one of the above technical solutions.

Therefore, the medical device has all the beneficial effects of the detector **200** as described in the above technical solutions, and the description thereof in detail will be omitted herein.
(55) As illustrated in FIG. **10**, in some examples, a scanning opening **330** may be formed on the medical device, and an examiner **350** can lie on a bearing bed **340** to be moved into the scanning opening **330** by moving the bearing bed **340**. Further, the radiation source **320** can emit the rays to the scanned object. The radiation source **320** may emit the fan-shaped or conical ray beams, and each ray beam includes several rays. The radiation source **320** can projects the ray beams from its focus to the scanned object. The plurality of detector modules **110** of the detector **200** is configured to detect rays attenuated by the scanned object, convert the optical signal of the received ray into the electrical signal, and retransmit the electrical signal to the upper computer for imaging.
(56) In the present disclosure, the terms “first”, “second”, “third”, etc., are merely for description, and cannot be understood as indicating or implying relative importance. It should be understood that “a plurality of” referred to herein means two or more, unless specified otherwise. Terms such as “installation”, “connection”, “connected to”, “fixed” and the like should be understood in a broad sense. For example, “connection” may be a fixed connection or a detachable connection or an integral connection; “connected to” may be directly or indirectly connected through an intermediate. For those of ordinary skill in the art, the specific meaning of the above-mentioned terms in the present disclosure can be understood according to specific circumstances.
(57) In the description of the present disclosure, it should be understood that, orientations or position relationships indicted by terms such as “upper”, “lower”, “left”, “right” “front”, “back”, and the like, are based on orientations or position relationships shown in the accompanying drawings, and is merely for the convenience of describing the present disclosure and simplifying the description, rather than indicating or implying that the associated device or element must have a specific orientation, or be constructed and operated in a specific orientation, and therefore cannot be understood as a limitation on the present disclosure.
(58) In the description of this specification, descriptions with reference to the terms “an embodiment”, “some embodiments”, “specific embodiments”, or the like, mean that specific features, structure, materials or characteristics described in conjunction with the embodiment or example are included in at least one embodiment or example of the present disclosure. In this specification, the schematic representations of the above terms do not necessarily refer to the same embodiment or example. Moreover, the described specific features, structures, materials or characteristics may be combined in any one or more embodiments or examples in a suitable manner.
(59) While preferred embodiments of the present disclosure have been described above, the present disclosure is not limited thereto. For those skilled in the art, various changes and modifications can be made to the present disclosure. Any modification, equivalent replacement, improvement, etc., made within the spirit and principle of the present disclosure shall fall within the scope of the present disclosure.

Claims

1. A detector module, comprising a plurality of detection sub-modules at least partially arranged in a stepped manner in a first direction, wherein: each of the plurality of detection sub-modules comprises a plurality of photoelectric conversion units arranged at intervals in a second direction intersecting with the first direction and one substrate, the plurality of photoelectric conversion units being disposed on the substrate to share the substrate; one of two adjacent detection sub-modules of the plurality of detection sub-modules is located at a higher step as a first detection sub-module, and the other one of the two adjacent detection sub-modules is located at a lower step and as a second detection sub-module; a first gap is formed between the plurality of photoelectric conversion units of the first detection sub-module; a second gap is formed between the plurality of

photoelectric conversion units of the second detection sub-module; and a width of the first gap in the second direction is smaller than a width of the second gap in the second direction.
2. The detector module according to claim 1, wherein: each gap between the plurality of photoelectric conversion units of the first detection sub-module is the first gap; and/or each gap between the plurality of photoelectric conversion units of the second detection sub-module is the second gap.
3. The detector module according to claim 1, wherein: a third gap is further formed between the plurality of photoelectric conversion units of the first detection sub-module, the third gap and the first gap being arranged in the second direction, and a width of the third gap in the second direction being different from the width of the first gap in the second direction; and/or a fourth gap is further present between the plurality of photoelectric conversion units of the second detection sub-module, the fourth gap and the second gap being arranged in the second direction, and a width of the fourth gap in the second direction being different from the width of the second gap in the second direction.
4. The detector module according to claim 3, wherein in the second direction, the width of the third gap is smaller than the width of the first gap, and the width of the fourth gap is smaller than the width of the second gap.
5. The detector module according to claim 4, wherein the width of the third gap in the second direction is equal to the width of the fourth gap in the second direction.
6. The detector module according to claim 4, wherein: an odd number of gaps are formed between the plurality of photoelectric conversion units of the first detection sub-module, the first gap being alternately arranged with the third gap, and a head gap and a tail gap of the odd number of gaps are each the third gap; and an odd number of gaps are present between the plurality of photoelectric conversion units of the second detection sub-module, the second gap being alternately arranged with the fourth gap, and a head gap and a tail gap of the odd number of gaps are each the fourth gap.
7. The detector module according to claim 1, wherein: the plurality of photoelectric conversion units of the first detection sub-module has a same width in the second direction; and/or the plurality of photoelectric conversion units of the second detection sub-module has a same width in the second direction.
8. The detector module according to claim 7, wherein the plurality of photoelectric conversion units of the first detection sub-module has a same width as the plurality of photoelectric conversion units of the second detection sub-module in the second direction.
9. The detector module according to claim 1, further comprising: a support on which the substrates of the plurality of detection sub-modules are disposed; wherein each of the plurality of detection sub-modules further comprises an analog-to-digital converter connected to the plurality of photoelectric conversion units of the detection sub-module, the plurality of photoelectric conversion units and the analog-to-digital converter of the detection sub-module being disposed on the substrate of the detection sub-module and arranged in the first direction, wherein the substrate of the first detection sub-module being superposed on the analog-to-digital converter of the second detection sub-module.
10. A detector, comprising a plurality of detector modules, each of the plurality of detector modules comprising a plurality of detection sub-modules at least partially arranged in a stepped manner in a first direction, wherein: each of the plurality of detection sub-modules comprises a plurality of photoelectric conversion units arranged at intervals in a second direction intersecting with the first direction and one substrate, the plurality of photoelectric conversion units being disposed on the substrate to share the substrate; one of two adjacent detection sub-modules is located at a higher step as a first detection sub-module, and the other one of the two adjacent detection sub-modules is located at a lower step and as a second detection sub-module; a first gap is formed between the plurality of photoelectric conversion units of the first detection sub-module; a second gap is formed

between the plurality of photoelectric conversion units of the second detection sub-module; a width of the first gap in the second direction is smaller than a width of the second gap in the second direction; and the plurality of detector modules is arranged in the second direction, and detection sub-modules of the plurality of detector modules at a same step are adjacent to each other.

11. The detector according to claim 10, wherein: a fifth gap is formed between adjacent first detection sub-modules; a sixth gap is formed between adjacent second detection sub-modules; and in the second direction, a width of the fifth gap is equal to the width of the first gap, and a width of the sixth gap is equal to the width of the second gap.

12. The detector according to claim 10, wherein the detection sub-modules at the same step have surfaces tangent to circles with a same radius.

13. The detector according to claim 10, wherein: each gap between the plurality of photoelectric conversion units of the first detection sub-module is the first gap; and/or each gap between the plurality of photoelectric conversion units of the second detection sub-module is the second gap.

14. The detector according to claim 10, wherein: a third gap is further formed between the plurality of photoelectric conversion units of the first detection sub-module, the third gap and the first gap being arranged in the second direction, and a width of the third gap in the second direction being different from the width of the first gap in the second direction; and/or a fourth gap is further present between the plurality of photoelectric conversion units of the second detection sub-module, the fourth gap and the second gap being arranged in the second direction, and a width of the fourth gap in the second direction being different from the width of the second gap in the second direction.

15. The detector according to claim 14, wherein in the second direction, the width of the third gap is smaller than the width of the first gap, and the width of the fourth gap is smaller than the width of the second gap.

16. The detector according to claim 15, wherein the width of the third gap in the second direction is equal to the width of the fourth gap in the second direction.

17. The detector according to claim 15, wherein: an odd number of gaps are formed between the plurality of photoelectric conversion units of the first detection sub-module, the first gap being alternately arranged with the third gap, and a head gap and a tail gap of the odd number of gaps are each the third gap; and an odd number of gaps are present between the plurality of photoelectric conversion units of the second detection sub-module, the second gap being alternately arranged with the fourth gap, and a head gap and a tail gap of the odd number of gaps are each the fourth gap.

18. The detector according to claim 10, wherein: the plurality of photoelectric conversion units of the first detection sub-module has a same width in the second direction; and/or the plurality of photoelectric conversion units of the second detection sub-module has a same width in the second direction.

19. The detector according to claim 18, wherein the plurality of photoelectric conversion units of the first detection sub-module has a same width as the plurality of photoelectric conversion units of the second detection sub-module in the second direction.

20. A medical device, comprising: a housing defining a scanning chamber; and a detection assembly disposed in the housing, the detection assembly comprising a detector comprising a plurality of detector modules, each of the plurality of detector modules comprising a plurality of detection sub-modules at least partially arranged in a stepped manner in a first direction, wherein: each of the plurality of detection sub-modules comprises a plurality of photoelectric conversion units arranged at intervals in a second direction intersecting with the first direction and one substrate, the plurality of photoelectric conversion units being disposed on the substrate to share the substrate; one of two adjacent detection sub-modules is located at a higher step as a first detection sub-module, and the other one of the two adjacent detection sub-modules is located at a lower step and as a second detection sub-module; a first gap is formed between the plurality of photoelectric

conversion units of the first detection sub-module; a second gap is formed between the plurality of photoelectric conversion units of the second detection sub-module; a width of the first gap in the second direction is smaller than a width of the second gap in the second direction; the plurality of detector modules is arranged in the second direction, and detection sub-modules of the plurality of detector modules at a same step are adjacent to each other; and the first direction is an extending direction of the scanning chamber.