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

(11) **EP 2 778 716 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
17.09.2014 Bulletin 2014/38

(21) Application number: **12860209.1**

(22) Date of filing: **20.12.2012**

(51) Int Cl.:
G01T 3/00 *(2006.01)* ***G01T 1/00*** *(2006.01)*

(86) International application number:
PCT/CN2012/087021

(87) International publication number:
WO 2013/091554 (27.06.2013 Gazette 2013/26)

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **22.12.2011 CN 201110436139**

(71) Applicant: **Nuctech Company Limited**
Tongfang Building
Shuangqinglu
Haidian District
Beijing 100084 (CN)

(72) Inventors:
- **ZHAO, Kun**
  Beijing 100084 (CN)
- **RUAN, Ming**
  Beijing 100084 (CN)

(74) Representative: **Witte, Weller & Partner**
Patentanwälte mbB
Königstrasse 5
70173 Stuttgart (DE)

(54) DETECTOR AND METHOD FOR SIMULTANEOUSLY DETECTING GAMMA RAY AND NEUTRON RAY USING SAME

(57) The present invention discloses a detector. The detector includes a detector crystal, configured to detect incident rays therein; a plurality of moderator layers, configured to moderate neutrons entering the moderator layer; and a plurality of converter layers, configured to react with said moderated neutrons. The moderator layers and the converter layers are overlapped with each other, and the moderator layers and the converter layers are located outside the detector crystal.

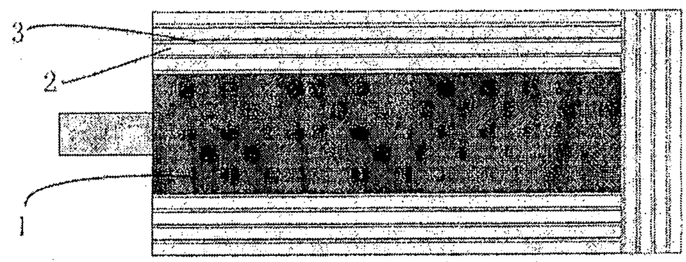

Fig. 1

EP 2 778 716 A1

Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Chinese Patent Application No.201110436139.7 filed on December 22, 2011 in the State Intellectual Property Office of China, the whole disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a detector for monitoring radioactive substances, while detecting neutron and gamma rays.

2. Description of the Related Art

[0003] ^{3}He proportional counter tube is one of the most common neutron detectors. It is a preferred neutron detector in the fields such as neutron energy spectrum measurement, particular nuclear material monitoring, and radioactive material monitoring, due to the characteristic of high detection efficiency or the like.

[0004] However, ^{3}He gas is a scarce resource and acquisition thereof is limited, so that the use of ^{3}He proportional counter tube is limited. To this end, the present invention proposes a new neutron detection device and a measuring method thereof, and the detection device in accordance with the present invention does not need ^{3}He proportional counter tube.

SUMMARY OF THE INVENTION

[0005] In accordance with one aspect of the present invention, it provides a detector, comprising:

a detector crystal, configured to detect incident rays therein;
a plurality of moderator layers, configured to moderate neutrons entering the moderator layer; and
a plurality of converter layers, configured to react with said moderated neutrons;
wherein the moderator layers and the converter layers are overlapped with each other, and the moderator layers and the converter layers are located outside the detector crystal.

[0006] Preferably, the moderator layer is made of polythene.

[0007] Preferably, the converter layer is made of copper or iron.

[0008] Preferably, the detector crystal is made of sodium iodide.

[0009] Preferably, each moderator layer has a thickness of 1-2 cm.

[0010] Preferably, each converter layer has a thickness of 1-4mm.

[0011] Preferably, the detector crystal is cuboid, and the detector crystal has the same surface area as that of the moderator layer or the converter layer.

[0012] In accordance with another aspect of the present invention, it provides a method of simultaneously detecting neutrons and gamma rays, comprising the steps of:

using the detector of the present invention to detect the gamma rays;
processing output signals of the detector;
analyzing pulse height of said signals, to record neutron counts or gamma counts.

[0013] Preferably, if the energy is in a range of 3-8 MeV, then it is recorded as a neutron count; and if the energy is less than 3 MeV, then it is recorded as a gamma count.

[0014] Preferably, with respect to an energy analysis of a gamma region, if a characteristic peak is present within the gamma region, then it is recorded as a gamma count.

[0015] The above described non-specific embodiments at least have one or more aspects of the advantages and effects:

Compared with the prior art, constituting materials of the present detector are easy to be obtained, and reduce the cost. In addition, the present detector has a large application scope, and relatively high sensitivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Figure 1 is a sectional view of a front side of a detector in accordance with one embodiment of the present invention; and
Figure 2 is a cross-sectional side view of the detector as shown in figure 1.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0017] Technical solutions of the present invention will be described hereinafter in more detail by the way of embodiment with reference to figures 1-2 of the attached drawings, wherein the same or like reference numerals refer to the same or like elements throughout the specification. The explanation to the embodiment of the present invention with referring to the accompanying drawings is intended to interpret the general inventive concept of the present invention, rather than being construed as a limiting to the present invention.

[0018] In accordance with one preferred embodiment of the present invention, as shown in Figs. 1 and 2, a detector includes a detector crystal 1, a multi-layer moderator or a plurality of moderator layers 2 and a multilayer converter or a plurality of converter layers 3. The moderator layer 2 is provided to moderate neutrons entering the moderator therein, and the converter layer 3 is provided to react with said moderated neutrons. The detector crystal 1 is arranged to detect incident rays therein. The moderator layers 2 overlap with the converter layers 3 each other, and the moderator layers 2 and the converter layers 3 are located outside the detector crystal 1. As shown in Fig.1, the moderator layers 2 and the converter layers 3 surround the detector crystal 1.

[0019] In accordance with one preferred embodiment, the detector crystal is made of sodium iodide, and of course, alternatively can be made of cesium iodide or lanthanum bromide. The sodium iodide detector has high energy resolution. In addition, it is preferable for the moderator layer 2 to be made of polyethylene, since it is an ideal material for moderating neutron. Iron or copper is an element which has relatively large thermal neutron capture reaction cross-section (iron σ_γ=2.56 target, copper σ_γ=3,78 target). The iron or copper can react with thermal neutron to emit high-energy gamma rays. Preferably, the converter layer 3 is made of iron or copper.

[0020] As shown in Fig. 1, preferably, the detector crystal 1 is cuboid. The detector crystal 1 has the same surface area as that of the moderator layer 2 or the converter layer 3. Each moderator layer 2 has a thickness of 1-2cm. Each converter layer 3 has a thickness of 1-4mm. The detector crystal 1, the moderator layers 2 and the converter layers 3 are fixed together by a housing. Alternative arrangement of the moderator layers and the converter layers can increase the probability of the capture reaction.

[0021] The working principle of the present invention is as follows: the neutrons entering moderator 2 are firstly moderated and become low-energy neutrons and subsequently, a portion of the low energy neutrons enter and react with converter layers 3with a certain probability, and then gamma rays (the energy thereof is less than 8MeV) are emitted. These gamma rays are detected by the detector and a signal thereof is processed and discriminated by a subsequent circuit. If the energy thereof is between 3 and 8 MeV, then it is recorded as a neutron count. Otherwise, with respect to the gamma rays entering the detector, a signal thereof is processed and discriminated by a subsequent circuit, and if the energy thereof is less than 3 MeV, then it is recorded as a gamma count (the gamma rays emitted from the gamma radioactive sources generally have energies less than 3 MeV).

[0022] In accordance with another aspect of the invention, the present invention also provides a method to simultaneously detect both neutrons and gamma rays. The detector of the present invention is used to detect the gamma rays. Signals from the detector are processed. The energies of the gamma rays are analysed to carry out the neutron counting and gamma ray counting.

[0023] Preferably, if the energy is in a range of 3MeV to 8MeV, then it is recorded as a neutron count; and if the energy is less than 3MeV, then it is recorded as a gamma count.

[0024] For common gamma rays, the energies thereof are mostly less than 3MeV. The output signals from the detector are divided into two regions. The one corresponding to energy less than 3 MeV is named as gamma region, in which the background count rate of gamma rays is very high. Another one corresponding to energy in the range of 3~8MeV is named as neutron region, in which the background count rate of gamma rays is very low. For capture gamma ray with energy less than 3 MeV, although it will be counted into gamma region, the number thereof is much less than that of gamma background within this region. Therefore, this substantially will not cause a false alarm of the gamma region. For capture gamma ray with energy larger than 3 MeV, the number thereof is approximately equal to that of gamma background within this region, and this will cause an alarm of the neutron region. For non-capture gamma ray with energy less than 3 MeV, it will be counted into the gamma region. For the non-capture gamma ray with energy larger than 3 MeV, although it will be counted into the neutron region, this substantially will not cause a false alarm of the neutron region, due to a very small number thereof.

[0025] If a neutron source has very large activity, then capture gamma rays with energies less than 3 MeV will have a large number. Thus, this probably will cause false alarm of the gamma region. One solution to this problem is to perform an energy spectrum analysis of the gamma region. Since capture gamma ray has relatively scattered energy distribution, it is difficult to generate a characteristic peak on the energy spectrum within the gamma region. Even if a charactering peak is formed, it is also possible to determine whether the gamma rays are from neutron capture reaction, in accordance with a peak position thereof. When the alarm is triggered within the gamma region, if the characteristic peak cannot be found within the energy spectrum of the gamma region, then it indicates that said alarm is caused by the neutron source with large activity; if a characteristic peak exists within the energy spectrum of the gamma region and belongs to a gamma radioactive source, then it indicates that this alarm is indeed caused by a gamma radioactive source.

[0026] Although some embodiments of the general inventive concept are illustrated and explained, it would be appreciated by those skilled in the art that modifications and variations may be made in these embodiments without departing from the principles and spirit of the general inventive concept of the disclosure, the scope of which is defined in the appended claims and their equivalents.

Claims

1. A detector, comprising:

a detector crystal, configured to detect incident rays therein;

a plurality of moderator layers, configured to moderate neutrons entering the moderator layer; and
a plurality of converter layers, configured to act with said moderated neutrons;
wherein the moderator layers and the converter layers are overlapped with each other, and the moderator layers and the converter layers are located outside the detector crystal.

2. The detector of claim 1, wherein the moderator layer is made of polythene.

3. The detector of claim 1, wherein the converter layer is made of copper or iron.

4. The detector of claim 1, wherein the detector crystal is made of sodium iodide.

5. The detector of claim 1, wherein each moderator layer has a thickness of 1-2 cm.

6. The detector of claim 1, wherein each converter layer has a thickness of 1-4mm.

7. The detector of claim 1, wherein the detector crystal is cuboid, and the detect crystal has the same surface area as that of the moderator layer or the converter layer.

8. A method of simultaneously detecting neutrons and gamma rays, comprising the steps of:

using the detector of any of claims 1-7 to detect the gamma rays;
processing output signals of the detector;
analysing pulse height of said signals, to record neutron counts or gamma counts.

9. The method of claim 8, wherein if the energy is in a range of 3-8 MeV, then it is recorded as a neutron count; and if the energy is less than 3 MeV, then it is recorded as a gamma count.

10. The method of claim 9, wherein with respect to an energy analysis of a gamma region, if a charactering peak is present within the gamma region, then it is recorded as a gamma count.

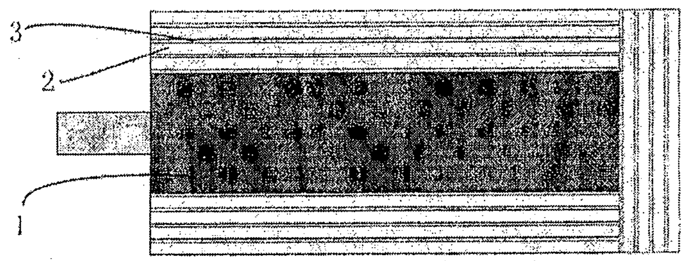

Fig. 1

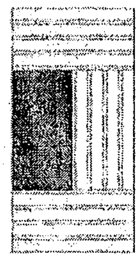

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/087021

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: G01T 3, G01T 1, G01N 23, A61B 6

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)

CNKI, CPRSABS, CNTXT, VEN: neutron, ray, radiation, moderation, moderator

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 102081166 A (NUCTECH CO., LTD.), 01 June 2011 (01.06.2011), description, page 3, line 25 to page 5, line 25, and figures 1 and 2	1-10
Y	CN 1981211 B (GSI GESELLSCHAFT FUR SCHWERIONENFORSCHUNG MBH), 11 May 2011 (11.05.2011), description, page 2, line 2 to page 3, line 35, and figure 1	1-10
A	CN 101329404 A (TSINGHUA UNIVERSITY), 24 December 2008 (24.12.2008), the whole document	1-10
A	CN 101158656 A (NANJING GUOSHENG TECHNOLOGY CO., LTD.), 09 April 2008 (09.04.2008), the whole document	1-10
A	US 7525101 B2 (THERMO NITON ANALYZERS LLC), 28 April 2009 (28.04.2009), the whole document	1-10
PX	CN 202372648 U (NUCTECH CO., LTD.), 08 August 2012 (08.08.2012), the whole document	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 February 2013 (26.02.2013)	**14 March 2013 (14.03.2013)**

Name and mailing address of the ISA/CN:
State Intellectual Property Office of the P. R. China
No. 6, Xitucheng Road, Jimenqiao
Haidian District, Beijing 100088, China
Facsimile No.: (86-10) 62019451

Authorized officer
WANG, Shuling
Telephone No.: (86-10) **62085649**

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2012/087021

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102081166 A	01.06.2011	None	
CN 1981211 B	11.05.2011	WO 2005106532 A2	10.11.2005
		DE 102004020979 A1	17.11.2005
		EP 1740976 A2	10.01.2007
		CN 1981211 A	13.06.2007
		JP 2007533984 A	22.11.2007
		US 2009039279 A1	12.02.2009
		US 7655921 B2	02.02.2010
		WO 2005106532 A3	20.04.2006
		JP 5044390 B2	10.10.2012
CN 101329404 A	24.12.2008	None	
CN 101158656 A	09.04.2008	CN 100595575 C	24.03.2010
US 7525101 B2	28.04.2009	US 2007272874 A1	29.11.2007
		WO 2007139915 A2	06.12.2007
		EP 2021831 A2	11.02.2009
		AU 2007267904 A1	06.12.2007
		CN 101443679 A	27.05.2009
		CA 2648767 A1	06.12.2007
		JP 2009538435 A	05.11.2009
		CN 101443679 B	23.05.2012
		AU 2007267904 B2	06.09.2012
CN 202372648 U	08.08.2012	None	

Form PCT/ISA/210 (patent family annex) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2012/087021

A. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both national classification and IPC

G01T 3/00 (2006.01) i

G01T 1/00 (2006.01) i

Form PCT/ISA/210 (extra sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- CN 201110436139 **[0001]**