(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 August 2002 (15.08.2002)

PCT

(10) International Publication Number
WO 02/063338 A1

(51) International Patent Classification[7]: G01T 1/20, A61B 6/14

(21) International Application Number: PCT/SE02/00149

(22) International Filing Date: 29 January 2002 (29.01.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0100382-1 7 February 2001 (07.02.2001) SE

(71) Applicant *(for all designated States except US)*: **LP RÖNTGENTEKNIK AB** [SE/SE]; Storgatan 73E, S-852 30 Sundsvall (SE).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **NELVIG, Per** [SE/SE]; Granvägen 4, S-852 35 Sundsvall (SE).

(74) Agents: **HEDBERG, Åke** et al.; Aros Patent AB, P.O. Box 1544, S-751 45 Uppsala (SE).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

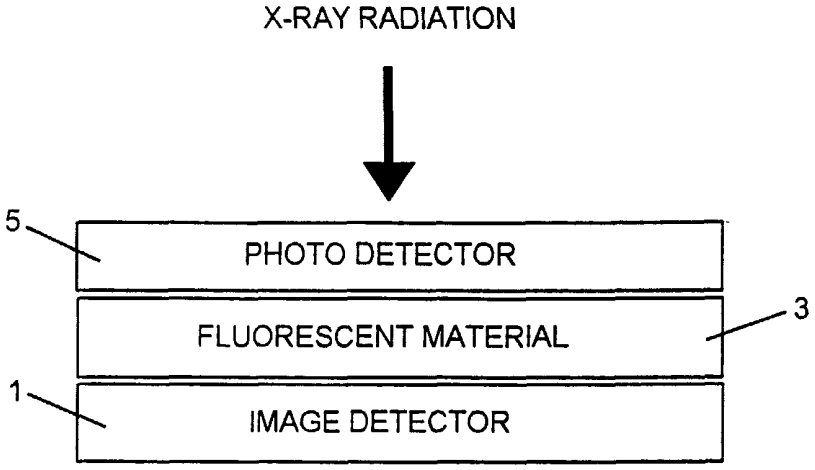
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE,*

[Continued on next page]

(54) Title: X-RAY DETECTOR



(57) Abstract: A thin photo detector (5) forming a single sensitive surface is positioned in front of a scintillating or fluorescent material (3) in front of an image detector (1). The light created in the scintillating or fluorescent material when the present device is subject to X-ray radiation then will hit both the photo detector and the image detector. An electric signal created in the photo detector (5) may then be utilised for deciding status of the imaging system and define a status of the imaging system dependent on whether exposure (radiation source active) takes place or not. The photo detector may in a preferred embodiment for instance constitute amorphous silicon deposited onto a substratre transparent for X-ray radiation and positioned close to a scintillating or fluorescent material in front of an image detector. However the photo detector in still another embodiment may as well be made from a semiconductor polymer. The three main components, photo detector (5), fluorescent screen (3) and image detector (1) are easily integrated into one imaging component. Due to the compact design possible, the present invention may advantageously be used for instance for dental X-ray examinations.

WO 02/063338 A1

KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

X-ray detector

TECHNICAL FIELD

The present invention relates to a detector device and more exactly to an X-ray image detector provided with a photo detector generating control signals.

BACKGROUND

In X-ray techniques today electronic detectors tend to replace the earlier utilised ordinary film, which after exposure had to be developed. Since 1986 different products have for instance been marketed for direct dental X-ray examinations. Most of the devices rely on Charge Coupled Device detector techniques (CCD). During last years also CMOS detectors have been introduced for imaging purposes in connection with X-ray examinations. The silicon based detectors all have been combined with an energy converter consisting of a fluorescent or scintillating material in order to increase efficiency.

Typical X-ray sources for dental X-ray imaging generally operate with an accelerating voltage of 60 – 90 kV giving a mean photon energy in the range 30 – 40 keV. The material thickness required to stop 80 % of the X-ray photons is found to be in the range 150 – 500 μm for commonly used scintillators. The primary interaction between a photon and the material, photoelectric absorption, is a single event. The light in the scintillator material is then generated by a large number of secondary reactions taking place within a few microns from the location of the primary interaction. As a result a flash of light is generated close to the spot of the primary interaction and radiated in all directions. Materials often used as scintillators have been based on cesium iodide (CsI) or terbium doped gadolinium oxy-sulphide (Gd_2O_2S:Tb) phosphor.

In many cases a thin plate of fibre optics has been used between the silicon detector and the fluorescent component in order to decrease the amount of X-ray radiation reaching the silicon detector and absorbed directly therein. Regarding the CCD detector different methods to increase its durability have

been used. Among other things the method of creating the channel limitations has been crucial as for commercial CCD detectors as the common LOCOS structure was considered to result in deficient radiation durability. Additionally a so called inverted mode or using another expression, MPP, has essentially increased the durability and decreased the dark current which in principle has made the fibre optical component unnecessary.

A further approach for increasing efficiency with improved resolution when using a scintillator device together with an image detector was recently demonstrated in an International Application WO00/43810 (Swedish patent SE-C2-513 538) to handle a situation whenever the X-ray photon absorption distance is much longer than the required pixel size.

To synchronise an imaging detector system and the radiation source (e.g. a dental X-ray apparatus) different methods have been used. EP-A1-0 415 075 discloses a dental X-ray diagnostic device using a radiation sensitive sensor at the back or at the side of an image detector for use in dental X-ray imaging. The detector could also be integrated in the silicon substrate forming a CCD. In WO92/22188 (US-A-6 002 742) a further method and system for triggering of an X-ray image sensor is disclosed using a number of X-ray sensitive diodes distributed over the back surface of a CCD image detector for dental X-ray examinations.

In GB-A-2 303 772 and GB-A-2 303 017 a manner to read and analyse the dark current of the CCD detector is disclosed. When the achieved signal suddenly overrides a threshold value defined this indicates that exposure has started and the CCD is then set to an integration state until enough time passed for a fully exposed image to be read out.

For CMOS detectors a non-destructive readout of pixels for instance has been used as well as other methods to discover and establish whether radiation is present or not in order to control and indicate a system status.

However there is still a need for a technique to easily obtain a general indication of X-ray radiation of the image sensor, which independent of the imaging detector itself provides a high sensitivity over the entire imaging surface.

SUMMARY OF THE INVENTION

According to the present invention a thin photo detector is additionally positioned in front of a scintillating or fluorescent material in front of an image detector. Generally a scintillating or fluorescent material is used to convert X-ray radiation into visible light. The light created in the scintillating or fluorescent material when the present device is subject to X-ray radiation then will hit both the photo detector and the image detector. An electric signal is then created in the photo detector, which signal may be utilised for deciding status of the imaging system and define a status of the imaging system dependent on whether exposure (radiation source active) takes place or not. The photo detector may in a preferred embodiment for instance constitute amorphous silicon deposited onto a substrate transparent for X-ray radiation and positioned close to a scintillating or fluorescent material in front of an image detector. However the photo detector in still another embodiment may as well be made from a semiconducting polymer. The three main components, photo detector, fluorescent screen and image detector are easily integrated into one imaging component. Due to the possible compact design, the present invention may advantageously be used for instance for dental X-ray examinations.

An X-ray image detector device for simultaneous imaging and creation of a status signal according to the present invention is set forth by the independent claim 1, and further embodiments are set forth by the dependent claims 2 to 8.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described by the following description to be read together with the appended drawings, wherein:

FIG. 1 illustrates a general view of an illustrative embodiment of a image detector according to the present invention;

FIG. 2 illustrates in a general view a second embodiment of an image detector according to the present invention, and

FIG. 3 illustrates a cross section of a third embodiment of an X-ray image detector according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates a general embodiment of an image detector realising the techniques according to the present invention. On top of an image detector **1**, preferably a CCD or a CMOS image detector, a fluorescent material **3** is positioned. Additionally a thin photo detector **5** is placed on top of the fluorescent material **3**. The fluorescent material **3** may typically be a CsI material, but may also constitute a terbium doped gadolinium oxy-sulphide phosphor (Gd_2O_2S:Tb).

Light arising in the fluorescent material layer **3** will hit both the photo detector **5** and the image sensor **1** when the device is subject to an X-ray radiation. An electric signal then will be created in the photo detector. For instance this signal is extracted for use as a measure indicating that an exposure is ongoing. In other words, an indication is achieved that the radiation source is active. This electric signal, as is apparent to a person skilled in the art, may by ordinary electronic means easily be integrated and used for a highly sensitive exposure control.

The photo detector in a preferred embodiment is advantageously a thin film cell of for instance amorphous silicon deposited onto a substrate fully transparent for X-ray radiation. The silicon surface of this photo detector is for highest possible sensitivity brought in direct contact with the fluorescent material **3**. The photo detector, according to the state of the art is provided

with electrical terminals for access of the current induced by light generated from the fluorescent material **3** when subject to X-ray radiation.

In a further embodiment this front photo detector may also be made from a semiconducting polymer and brought in contact with the surface of the fluorescent material facing the radiation source.

Figure 2 indicates a second embodiment of an X-ray imaging detector provided with the present photo detector. In Figure 2 a fibre optical interface **7** is inserted between the fluorescent material **3** and the imaging detector **1** to further utilise the possible resolution of the imager, for instance a CCD cell. The three main components, photo detector **5**, fluorescent screen **3** and image detector **1** are easily integrated into one imaging component. Due to the compact design possible, the present invention may advantageously be used for instance for dental X-ray examinations.

In yet another embodiment the fluorescent material layer **3** and the fibre optical interface **7** may be replaced by a fluorescent screen forming tubes of fluorescent material of for instance CsI having a diameter corresponding to the pixel size of the image detector **1**. Such an interface to the imager will for instance be equal to what is disclosed by the previously mentioned International Publication WO00/43810, however with the difference that the pore matrix, forming tubes for fluorescent material, will be open in both ends to transmit light also to the additional photo detector. In Figure 3 is demonstrated an embodiment illustrating an interface combining a photo detector **5** according to the present invention and a pore matrix **13** filled with scintillating material **11**. Some of the high efficiency of the original matrix device will be lost but resolution will still be gained in the same way as disclosed by the International Publication WO00/43810. It may be noticed that the pore channels of the matrix filled with scintillating material **11** are aligned with each pixel **15** of the image detector **1**. The silicon **5** on the X-ray transparent material **9** of the photo detector will serve as one single photo element covering the entire surface of the image detector **1**. As

illustrated an X-ray photon will give rise to several photons producing visible light, which due to the channels of the matrix will be transferred both to a specific pixel of the image detector and to the photo detector. The detector will integrate all photons arising from X-ray radiation over the entire detector surface. A similar function is also obtained in the second embodiment of Figure 2 utilising fibre optics between the fluorescent material and the image detector.

It will be apparent to a person skilled in the art that the present invention may be modified and altered in many ways without departing from the scope of the invention, which is defined by the appended claims.

CLAIMS

1. An X-ray image detector device for simultaneous imaging and creation of a status signal, **characterised in**

an imaging detector device (1);

a fluorescent component (3) positioned above a surface of the imaging detector device (1) facing an X-ray radiation source;

an additional photo detector (5) overlying a surface of the fluorescent component (3) facing the X-ray radiation source, the additional photo detector simultaneously with the imaging detector receiving light created by the fluorescent component for generating a signal indicating presence of X-ray radiation.

2. The device according to claim 1, **characterised in** that the imaging detector device (1) constitutes a Charge Coupled Device (CCD).

3. The device according to claim 1, **characterised in** that the imaging detector device (1) constitutes a CMOS image detector.

4. The device according to claim 1, **characterised in** that the fluorescent or scintillating component (3) contains cesium iodide (CsI) or terbium doped gadolinium oxy-sulphide (Gd_2O_2S:Tb) phosphor.

5. The device according to claim 1, **characterised in** that the additional photo detector (5) is a thin cell deposited onto a surface of the fluorescent component facing the X-ray radiation source.

6. The device according to claim 5, **characterised in** that the thin cell constitutes amorphous silicon deposited onto the fluorescent component.

7. The device according to claim 5, **characterised in** that the thin cell constitutes a semiconducting polymer.

8. The device according to claim 1, **characterised in** that a fibre optical device (7) is inserted between the fluorescent material (3) and the image detector (1) in order to increase imaging resolution.

9. The device according to claim 1, **characterised in** that that a pore matrix (13) filled with fluorescent material (3) or scintillating material (11) is inserted between the photo detector (5) and the image detector (1).

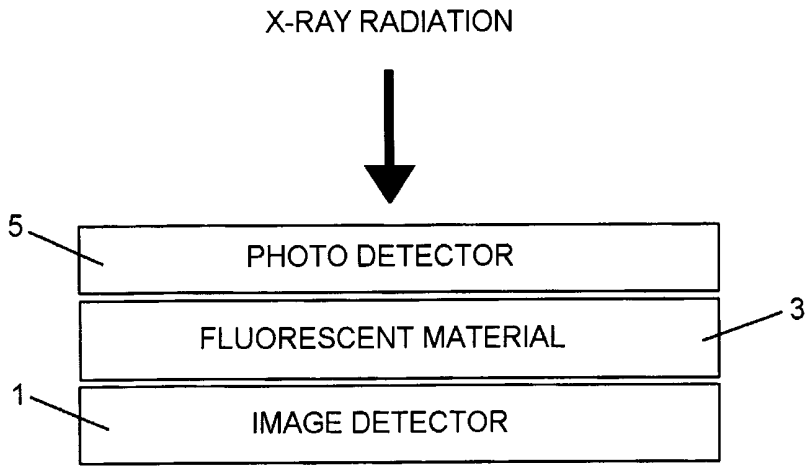

X-RAY RADIATION
5
PHOTO DETECTOR
FLUORESCENT MATERIAL
3
1
IMAGE DETECTOR

Fig. 1

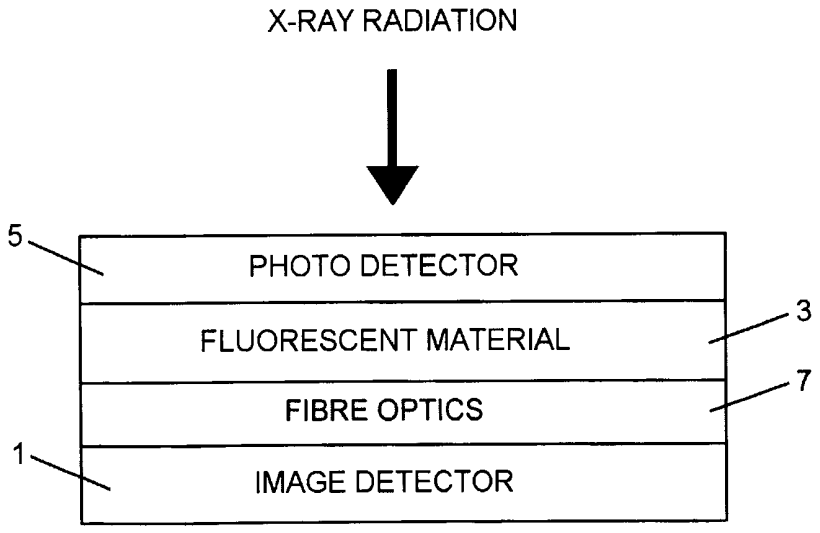

X-RAY RADIATION
5
PHOTO DETECTOR
FLUORESCENT MATERIAL
3
FIBRE OPTICS
7
1
IMAGE DETECTOR

Fig. 2

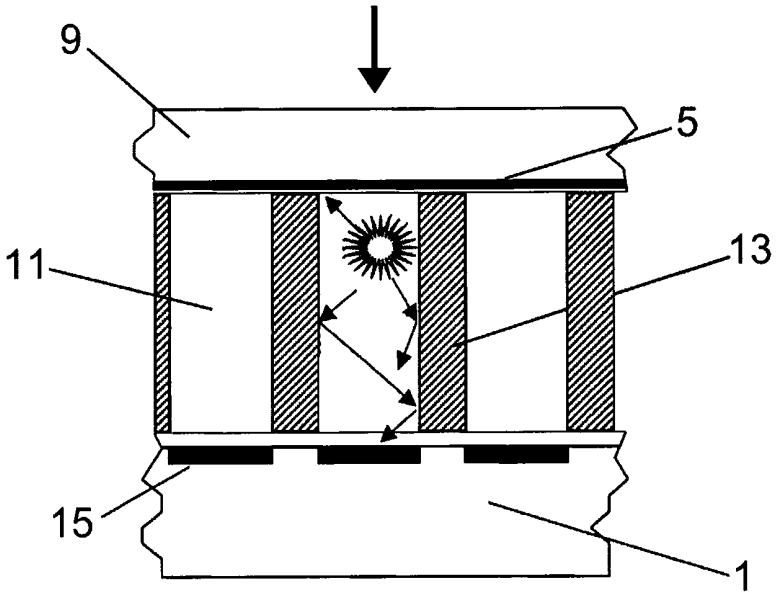


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00149

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G01T 1/20, A61B 6/14
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)

IPC7: G01T, A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5138166 A (TAKAO MAKINO ET AL), 11 August 1992 (11.08.92), abstract ---	1-9
A	US 5331166 A (KOEI YAMAMOTO ET AL), 19 July 1994 (19.07.94), abstract ---	1-9
A	US 5563414 A (HARTMUT SKLEBITZ), 8 October 1996 (08.10.96), abstract ---	1-9

[X] Further documents are listed in the continuation of Box C. [X] 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
28 May 2002	30 -05- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson/mj Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00149

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 7027864 A (FUJI PHOTO FILM CO LTD) 1995-01-31 (abstract) World Patents Index (online). London, U.K.: Derwnt Publications, Ltd. (retived on 2002-05-27). Retrived From EPO WPI Database. DW199514, Accession No.1995-102544 -- --------	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

01/05/02

International application No.
PCT/SE 02/00149

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5138166 A	11/08/92	DE 4138659 A	27/05/92
		FI 915538 A	27/05/92
		JP 4021024 A	24/01/92
US 5331166 A	19/07/94	DE 4235527 A,C	29/04/93
		FI 924814 A	26/04/93
		JP 3228975 B	12/11/01
		JP 5130991 A	28/05/93
		JP 5130990 A	28/05/93
US 5563414 A	08/10/96	DE 19503034 A	09/05/96
		DE 59501697 D	00/00/00
		EP 0710985 A,B	08/05/96
		JP 8211155 A	20/08/96