



US007869559B2

(12) **United States Patent**  
**Ikhlef et al.**

(10) **Patent No.:** **US 7,869,559 B2**  
(45) **Date of Patent:** **Jan. 11, 2011**

(54) **X-RAY DETECTOR METHODS AND APPARATUS**

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 44 days.

(21) Appl. No.: **11/551,019**

(22) Filed: **Oct. 19, 2006**

(65) **Prior Publication Data**

US 2008/0101534 A1 May 1, 2008

(51) **Int. Cl.**  
**A61B 6/00** (2006.01)

(52) **U.S. Cl.** ..... **378/5**; 378/19; 378/98.8; 378/98.9

(58) **Field of Classification Search** ..... 378/5, 378/19, 98.8, 98.9

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,392,235 A \* 7/1983 Houston ..... 378/10  
4,637,040 A 1/1987 Sohval et al.  
5,499,283 A \* 3/1996 Toki ..... 378/146

5,570,403 A \* 10/1996 Yamazaki et al. .... 378/5  
5,841,832 A \* 11/1998 Mazess et al. .... 378/56  
6,041,097 A 3/2000 Roos et al. .... 378/62  
6,128,365 A \* 10/2000 Bechwati et al. .... 378/57  
6,428,206 B1 \* 8/2002 Watanabe ..... 378/197  
6,473,486 B2 10/2002 Hoffiman ..... 378/19  
6,480,562 B2 11/2002 Jiang et al. .... 378/19  
6,480,563 B2 11/2002 Hoffiman et al. .... 378/19  
6,528,795 B2 3/2003 Kurfess et al. .... 250/370.1  
6,553,096 B1 \* 4/2003 Zhou et al. .... 378/122  
6,654,443 B1 11/2003 Hoffiman ..... 378/19  
6,704,391 B2 3/2004 Hoffiman et al. .... 378/98.8  
6,735,274 B1 \* 5/2004 Zahavi et al. .... 378/15  
6,891,166 B2 5/2005 Brahme et al. .... 250/389  
7,092,481 B2 8/2006 Hoffiman ..... 378/19  
7,778,383 B2 \* 8/2010 Koehler et al. .... 378/5  
2003/0161437 A1 8/2003 Hoffiman ..... 378/19  
2005/0031075 A1 \* 2/2005 Hopkins et al. .... 378/57  
2005/0056829 A1 3/2005 Green et al. .... 257/40  
2005/0111612 A1 \* 5/2005 Ikhlef et al. .... 378/19  
2009/0147910 A1 \* 6/2009 Edic et al. .... 378/5

\* cited by examiner

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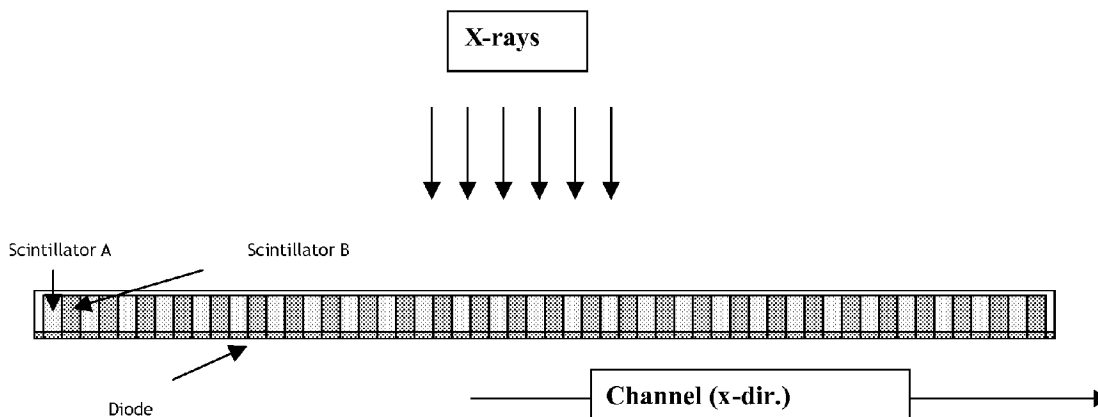
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(57) **ABSTRACT**

A method includes performing an x-ray focal spot deflection to generate two complete projections from two different channels of an x-ray detector, wherein the channels are purposefully different from each other in some respect other than being different channels.

**8 Claims, 3 Drawing Sheets**



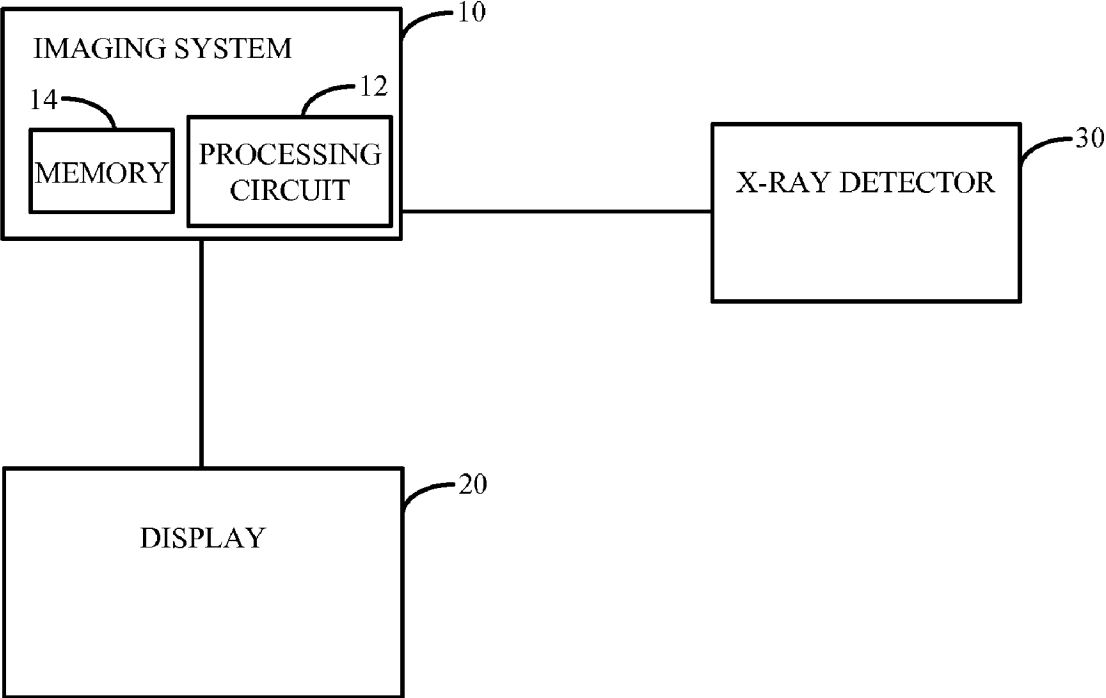


Figure 1

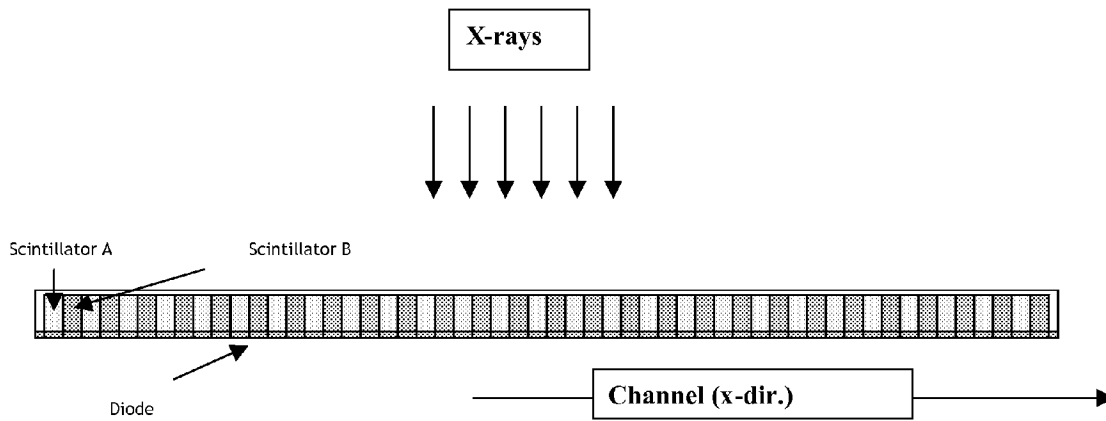


Figure 2

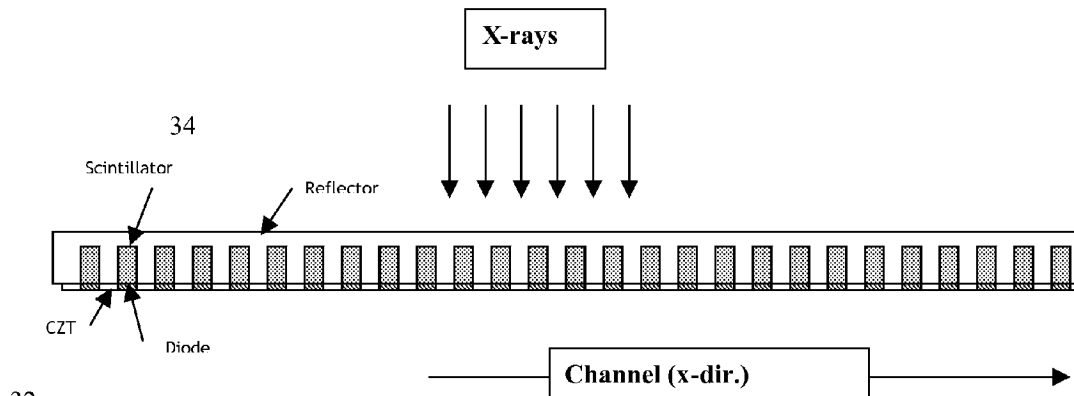


Figure 3

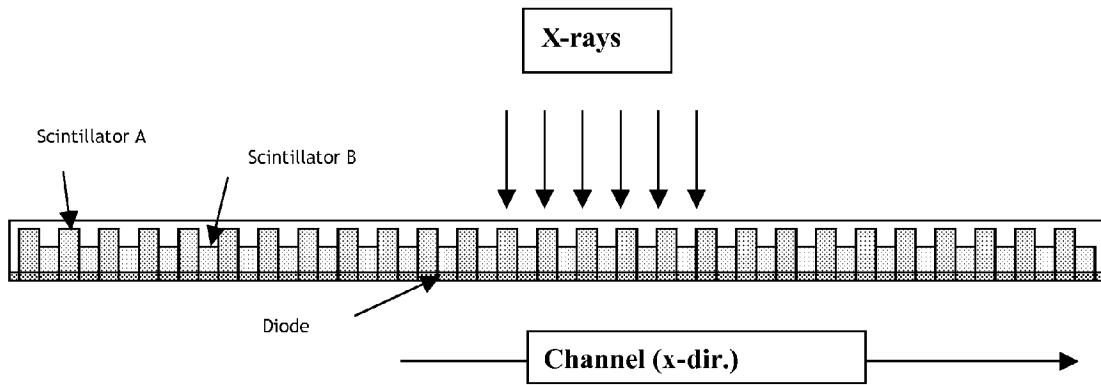


Figure 4

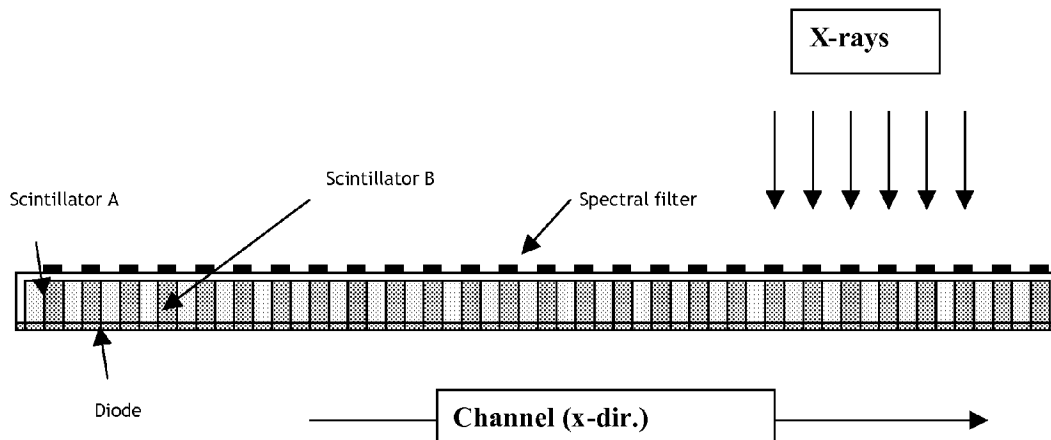


Figure 5

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## X-RAY DETECTOR METHODS AND APPARATUS

### BACKGROUND OF THE INVENTION

This invention relates generally to diagnostic imaging methods and apparatus, and more particularly, to methods and apparatus that provide detectors that are useful in computed tomography (CT).

Most multi-slice CT scanners are built with detectors composed of scintillator/photodiodes arrays. The photodiodes arrays are mainly based on front-illuminated technology. However, new designs based on back-illuminated photodiodes are being developed for CT machines to overcome the challenge of the higher number of runs and connections required. Current CT detectors generally use scintillation crystal/photodiode arrays, where the scintillation crystal absorbs x-rays and converts the absorbed energy into visible light. A photodiode is used to convert the light to an electric current. The electric current is read and the reading is proportional to the total energy absorbed. In these designs, the signal detected by the diode represents the integrated energy of the x-ray flux, during a short period of time, without any discrimination of energy.

Recently new ideas of CT detectors are being investigated for energy discrimination purposes using particularly direct conversion x-ray detector (or photoconductor) material such as CZT, CdTe, PbO, and etc., based photo-detectors. In this document, all direct conversion x-ray detectors are referred to as direct conversion material (CDM) detectors. These detectors are capable of photon counting and then measuring the energy of every photon. However, there is still a major challenge to overcome in order to achieve good CT performance and quality. Most of these detectors, working in photon counting modes are limited in their counting rate, either by pile-up effect, saturation, dynamic range, etc.

Besides, these detectors typically saturate at relatively low x-ray flux levels, which makes the detector feasible only in very low flux conditions. Therefor, described below is a detector which can be used in high x-ray flux environments. One way to overcome this limitation (limited count rate) is to find a method to provide energy information using integrating detectors such as in conventional CT systems. For this purpose, dual KVp systems can respond to the need because they do not suffer from count-rate limitations, as they typically used conventional detectors, operating in integrating mode. However, since the two data sets are acquired some distance apart in space or in time, this approach will be limited in its ability to resolve rapid changes in anatomy due to organ motion. When combined with a data acquisition system which is capable of resolving the energy of individual photon events, the system provides energy information which is not available in conventional CT. The advantage is that the energy information is provided simultaneously which enables the avoidance of motion related errors.

The proposed invention provides energy discrimination by interleaving data channels with different spectral responses. The combination of a) interleaving of channels having different spectral sensitivities and b) focal spot deflection will lead to a CT system with two or several images at different x-ray

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energies, or spectral windows. This patent describes the different ways of achieving detectors with different spectral responses.

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### BRIEF DESCRIPTION OF THE INVENTION

In one aspect, a method includes performing an x-ray focal spot deflection to generate two complete projections from two different channels of an x-ray detector, wherein the channels are purposefully different from each other in some respect other than being different channels.

In another aspect, a computer is configured to perform an x-ray focal spot deflection, and receive data forming two complete projections from two different channels of an x-ray detector, wherein the channels are purposefully different from each other in some respect other than being different channels.

In yet another aspect, a system is provided. The system includes an x-ray source, and an x-ray detector positioned to receive x-rays emitted from the source; wherein the detector includes at least two channels wherein the channels are purposefully different from each other in some respect other than being different channels.

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### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a computed tomography system.

FIG. 2 illustrates one embodiment, using two types of scintillators.

FIG. 3 illustrates that the detector can be built in different ways, and, more specifically, FIG. 3 illustrates a detector with a CDM detector portion and a scintillator portion.

FIG. 4 illustrates again that the detector may be built in different manners and, more particularly, FIG. 4 illustrates a detector with different thicknesses of scintillator material.

FIG. 5 illustrates again that the detector may be built in different manners and, more particularly, FIG. 5 illustrates a detector with a metallic or any absorptive filter on every other channel.

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### DETAILED DESCRIPTION OF THE INVENTION

There are herein described methods and apparatus useful for imaging systems such as, for example, but not limited to an x-ray system. The apparatus and methods are illustrated with reference to the figures wherein similar numbers indicate the same elements in all figures. Such figures are intended to be illustrative rather than limiting and are included herewith to facilitate explanation of an exemplary embodiment of the apparatus and methods of the invention. More particularly, herein described is a detector that enables the acquisition of x-ray images with different spectral contents using two different types of pixels (channels), wherein the channels are purposefully different from each other in some respect other than being different channels. The combination of this detector with focal spot deflection or an interpolation algorithm leads to an acquisition of two projections (images) of different spectral contents without losing the spatial resolution or image quality.

Herein described are methods and apparatus that enable the measurement of x-rays through two different mechanisms. In one embodiment, a detector is provided where the channels have different spectral properties and are interleaved in the channel direction (in the plane or the x-direction). In order to have a full set of data to reconstruct the images, one can imagine switching (deflecting) the focal spot in the channel direction by an equivalent distance of a cell (channel) from

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view to view (in time domain) or other algorithm based on interpolation between channels and slices. In this case, the projection data from each detector type can be acquired during one full rotation with the desired x-direction resolution. Some known systems employ focal spot position switching, for example, see U.S. Pat. No. 4,637,040.

FIG. 1 illustrates an imaging system **10** with an associated display **20**. Imaging system **10** can be of any modality, but in one embodiment, system **10** is a CT system. In another embodiment, system **10** is a dual modality imaging system such as a combined CT/PET system and data can be processed in one modality (e.g., CT) and the processed data can be transferred to the other modality (e.g., PET). Display **20** can be separate from system **10** or integrated with system **10**. System **10** includes an acquisition device such as an x-ray radiation detector **30**.

The detector **30** can be built in different ways. FIG. 2 illustrates one embodiment, using two types of scintillators. In this configuration, one can imagine using just two different scintillating materials from one channel to another. The scintillating material for odd channels can be chosen to be spectrally different from the material of the even channels. In this case, combined with an appropriate focal spot deflection in x-direction, one can acquire the projection from both scintillators in one rotation. It is contemplated that the benefits of the invention accrue to embodiments with more than two different scintillator materials. For example, 3, 4, or 5 different interleaved channels of different scintillating materials could be done.

FIG. 3 illustrates that the detector **30** can be built in different ways, and more specifically FIG. 3 illustrates a detector with a CDM detector portion **32** and a scintillator portion **34**.

In this configuration, one can imagine using two different detectors and materials composing the channels, mixing photon counting detector and a scintillator type detector. One can imagine, the odd channels to be composed of photon counting detector such as using CDM only and the even channels to be integrating detectors based on scintillators (conventional detectors). In this case, combined with an appropriate focal spot deflection in the x-direction, one can acquire the projection data from both scintillators and CDM detectors in one rotation, and with the right in-plane resolution.

FIG. 4 illustrates again that the detector **30** may be built in different manners and, more particularly, FIG. 4 illustrates a detector with different thicknesses of scintillator material.

In this configuration, one can imagine using the same scintillating material, from one channel to another but with different thickness. The scintillating material for odd channels can be chosen to be shorter or longer than the material of the even channels to achieve a significant difference in the spectral response from each. In this case, combined with the appropriate focal spot deflection in the x-direction, one can acquire the projection data from both scintillators in one rotation with different spectral content.

FIG. 5 illustrates again that the detector **30** may be built in different manners and, more particularly, FIG. 5 illustrates a detector with a metallic filter on every other channel. Of course, the filter may not be metallic, any x-ray attenuating material may be used.

In this configuration, one can imagine using the same or different scintillating material, from one channel to another but with different spectral filtration from one channel to another. For example, a metallic filter to achieve a specific spectral window can cover the scintillating material for odd channels. The even channels can be left without a filter. Alternatively, filters can be used on all channels using different filter types on different channels. For example, one filter type

can be used on the even channels and another filter type used on the odd channels. One commonality of all the embodiments described herein is that the channels are purposefully different from each other in some respect other than being different channels. In this case, combined with the appropriate focal spot deflection in x-direction, one can acquire the projection data from both scintillators in one rotation with different spectral windows. Additionally all the above described ways to differentiate the channels may be combined in all manners. For example different scintillating material can be used for the scintillators at different heights and a filter can be used with them. Additionally it is contemplated that they are could be other ways to differentiate one channel from another, and these un-described ways are not meant to be excluded.

Technical effects include that by using purposely different channels to obtain spectrally different data, one can perform at least one of a tissue differentiation and/or a material decomposition as is known in Energy Discrimination CT (EDCT).

Technical effects also include: 1. Energy discrimination using the same scintillator. 2. Energy discrimination by combining CDM detector and a scintillator. 3. Photon counting and obtaining an integrated signal at the same time. 4. Using the integrated signal to compensate or correct for the saturation of CDM detector under a high flux rate. 5. Calibrating the integrated signal to measure the flux rate. And, 6. Using of the same KV to achieve the spectral discrimination. In other words during a scan the x-ray tube KV is maintained constant, but the effect of changing the x-ray tube KV is obtained by using at least two channels that are different.

The x-ray imaging system **10** includes a processing circuit **12**. The processing circuit **12** (e.g., a microcontroller, microprocessor, custom ASIC, or the like) is coupled to a memory **14** and a display device **20**. The memory **14** (e.g., including one or more of a floppy disk drive, CD-ROM drive, DVD drive, magnetic optical disk (MOD) device, or any other digital device including a network connecting device such as an Ethernet device for reading instructions and/or data from a computer-readable medium, such as a floppy disk, or another digital source such as a network or the Internet, as well as yet to be developed digital means, and the like) stores imaging data.

The memory **14** may also store a computer program including instructions executed by the processing circuit to implement the functions described herein. The processing circuit **12** provides an image for display on a device **20**. The detector **30** may be a flat panel solid state image detector, for example, although conventional film images stored in digital form in the memory may also be processed. In one embodiment, the processing circuit **12** executes instructions stored in firmware (not shown).

Of course, the methods described herein are not limited to practice in system **10** and can be utilized in connection with many other types and variations of imaging systems. In one embodiment, the processing circuit **12** is a computer that is programmed to perform functions described herein, and, as used herein, the term computer is not limited to just those integrated circuits referred to in the art as computers, but broadly refers to computers, processors, microcontrollers, microcomputers, programmable logic controllers, application specific integrated circuits, and other programmable circuits. Although the herein described methods are described in a human patient setting, it is contemplated that the benefits of the invention accrue to non-human imaging systems such as those systems typically employed in small animal research. Although the herein described methods are described in a

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medical setting, it is contemplated that the benefits of the invention accrue to nonmedical imaging systems such as those systems typically employed in an industrial setting or a transportation setting, such as, for example, but not limited to, a baggage scanning CT system for an airport or other transportation center.

As used herein, an element or step recited in the singular and proceeded with the word “a” or “an” should be understood as not excluding plural said elements or steps, unless such exclusion is explicitly recited. Furthermore, references to “one embodiment” of the present invention are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

Exemplary embodiments are described above in detail. The assemblies and methods are not limited to the specific embodiments described herein, but rather, components of each assembly and/or method may be utilized independently and separately from other components described herein.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A computed tomography (CT) system comprising:
  - an x-ray source configured to emit x-rays;
  - an x-ray detector having a row of detectors positioned to receive x-rays emitted from the x-ray source, the x-ray detector comprising:
    - a diode;
    - a plurality of even detector cells having a first spectral property; and
    - a plurality of odd detector cells having a second spectral property;
  - wherein the plurality of even detector cells and the plurality of odd detector cells are arranged on the diode in an alternating pattern; and

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a computer configured to:

- cause the x-ray source to emit x-rays towards alternate even and odd detector cells along a length of the x-ray detector in a channel direction; and
  - cause one of focal spot deflection or an interpolation algorithm to acquire two projections of different spectral quality.
2. The system of claim 1 wherein the computer is further configured to acquire the two projections of different spectral quality during one full rotation of the x-ray detector.
  3. The system of claim 1 wherein the computer is further configured to switch a focal spot in the channel direction by an equivalent distance of a channel.
  4. The system of claim 1 wherein the interpolation algorithm comprises interpolation between one of channels and slices.
  5. The system of claim 1 wherein the plurality of even detector cells comprise a first scintillating material; and wherein the plurality of odd detector cells comprise a second scintillating material.
  6. The system of claim 1 wherein the plurality of even detector cells comprise scintillators; and wherein the plurality of odd detector cells comprise direct conversion material (CDM) detectors.
  7. The system of claim 1 wherein the plurality of even detector cells comprise a first thickness; and wherein the plurality of odd detector cells comprise a second thickness.
  8. The system of claim 1 wherein the plurality of even detector cells comprise filtered detector cells; and wherein the plurality of odd detector cells comprise unfiltered detector cells.

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