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X-ray computed tomography system utilizing a cadmium telluride detector

Eiichi Sato[a], Seiichiro Nomiya[b], Keitaro Hitomi[c], Hideaki Onabe[b], Toshiaki Kawai[d], Akira Ogawa[e], Shigehiro Sato[f] and Toshio Ichimaru[g]

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Abstract

A simple x-ray computed tomography (CT) system utilizing a cadmium telluride detector is described. The CT system is of the first generation type and consists of an x-ray generator, a turn table, a translation table, a motor drive unit, a cadmium telluride detector, an interface unit for the detector, and a personal computer (PC). Tomography was performed by the repetition of the translation and rotation of an object. The maximum values of the tube voltage and the tube current were 110 kV and 2.0 mA, respectively. Tomography was performed at a tube voltage of 60 kV and a current of 1.5 mA.

Keywords: x-ray CT, CdTe detector, single detector, first generation CT, biomedical tomograms

1. Introduction

So far, we have developed several different flash x-ray generators in order to perform high-speed monochromatic radiography.[1-7] In particular, plasma flash x-ray generators produce clean K-series characteristic rays because bremsstrahlung rays are absorbed effectively by weakly ionized metal plasmas consisting of metal ions and electrons.

To perform real-time radiography, a characteristic x-ray generator[8,9] with a demountable tube has been developed, and clean molybdenum K-series characteristic x-rays have been produced utilizing angular dependence of bremsstrahlung x-rays. In addition, a cerium x-ray generator[10-12] has been developed to perform iodine K-edge angiography using cerium K-rays.

Cadmium telluride (CdTe) detectors are useful for counting x-ray photons and for determining their

[a] Department of Physics, Iwate Medical University, 2-1-1 Nishitokuta, Yahaba 028-3694, Japan
[b] Raytech Inc., 5-6-27 Youtou, Utsunomiya 321-0904, Japan
[c] Department of Electronics and Intelligent systems, Tohoku Institute of Technology, 35-1 Yagiyama Kasumi-cho, Taihaku-ku, Sendai 982-8577, Japan
[d] Electron Tube Division #2, Hamamatsu Photonics K. K., 314-5 Shimokanzo, Iwata 438-0193, Japan
[e] Department of Neurosurgery, School of Medicine, Iwate Medical University, 19-1 Uchimaru, Morioka 020-8505, Japan
[f] Department of Microbiology, School of Medicine, Iwate Medical University, 19-1 Uchimaru, Morioka 020-8505, Japan
[g] Department of Radiological Technology, School of Health Sciences, Hirosaki University, 66-1 Honcho, Hirosaki 036-8564, Japan

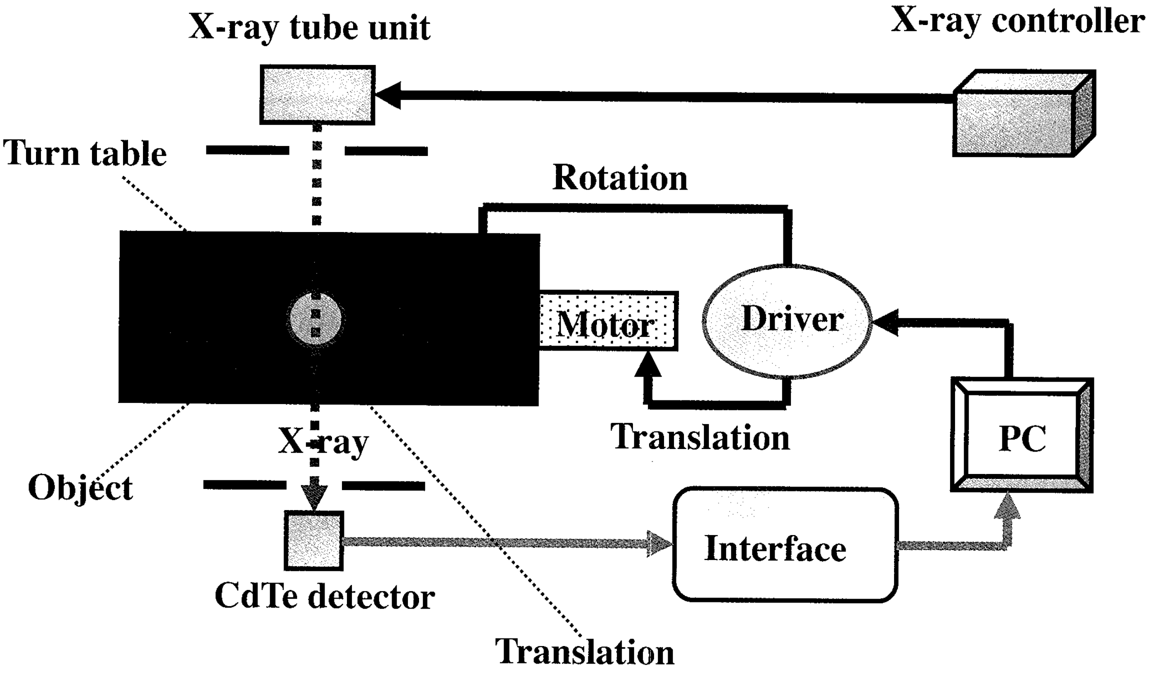

Fig. 1. Block diagram of a simple x-ray CT system utilizing a CdTe detector.

photon energies. Using these detectors, x-ray spectra can be measured using a multi-channel analyzer (MCA), and monochromatic photon-counting radiography can be performed by determining the photon energy and the energy width. In conjunction with a current amplifier, the CdTe detector is employed as a high-sensitive x-ray and γ-ray detector.

In our research, we developed a simple x-ray computed tomography (CT) system utilizing a CdTe detector driven in a current mode and used it to perform preliminary biomedical tomography.

2. Experimental Setup

Figure 1 shows the block diagram of a simple x-ray computed tomography (CT) system utilizing a CdTe detector (Fig. 2). The CT system is of the first generation type and consists of an x-ray generator, a turn table, a translation table, a motor drive unit, the CdTe detector, an interface unit for the detector, and a personal computer (PC). Tomography was performed by the repetition of the translation and rotation of an objects. The turn table and the translation table are driven by two motors, respectively. The x-ray intensity is detected by the CdTe detector, and the intensity signals are sent to the PC via an interface. The pitches of translation and rotation are selected corresponding to the objectives, and the spatial resolution improves with decreasing the two pitches.

The x-ray generator consists of a main controller and an x-ray tube unit with a Cockcroft-Walton circuit and a 0.5-mm-focus x-ray tube. The tube voltage, the current, and the exposure time can be controlled by the controller. The main circuit employs the Cockcroft-Walton circuit in order to decrease the dimensions of the tube unit. In the x-ray tube, positive and negative high voltages are applied to the anode and cathode electrodes, respectively. The filament heating current is supplied by an AC power supply in the controller in conjunction with an insulation transformer. The maximum tube voltage and current of the generator are 110 kV and 2.00 mA, respectively. In this experiment, the tube voltage applied was from 50 to 70 kV, and the tube current was 1.50 mA.

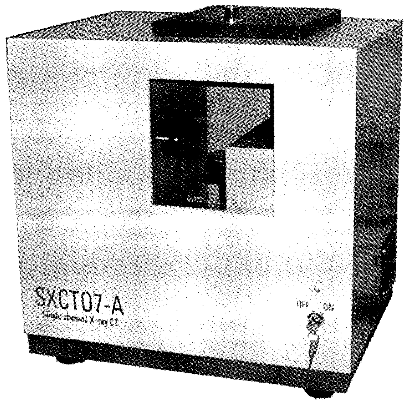

Fig. 2. X-ray CT system.

3. X-ray spectra from x-ray generator

In order to measure x-ray spectra, we employed a CdTe detector (Amptek, XR-100T) (Fig. 3). According to increases in the thickness of aluminum filter at a constant tube voltage of 60 kV, the bremsstrahlung peak energy increased, and the bremsstrahlung intensity decreased. Using a 3.0-mm-thick aluminum filter, both the maximum photon energy and the peak bremsstrahlung energy increased when the tube voltage was increased.

4. Tomography

Tomography was performed with a tube voltage of 60 kV and an aluminum filter thickness of 3.0 mm. The pitches of translation and rotation were 0.25 mm and 1.0°, respectively. Fig. 4 shows a tomogram of a piece of wood, and the tree rings are visible. A tomogram of an apple is shown in Fig. 5, and a cavern in the apple can be seen. Figures 6 and 7 show tomograms of a fish and a raw egg, respectively. A fish dorsal and a yolk are seen.

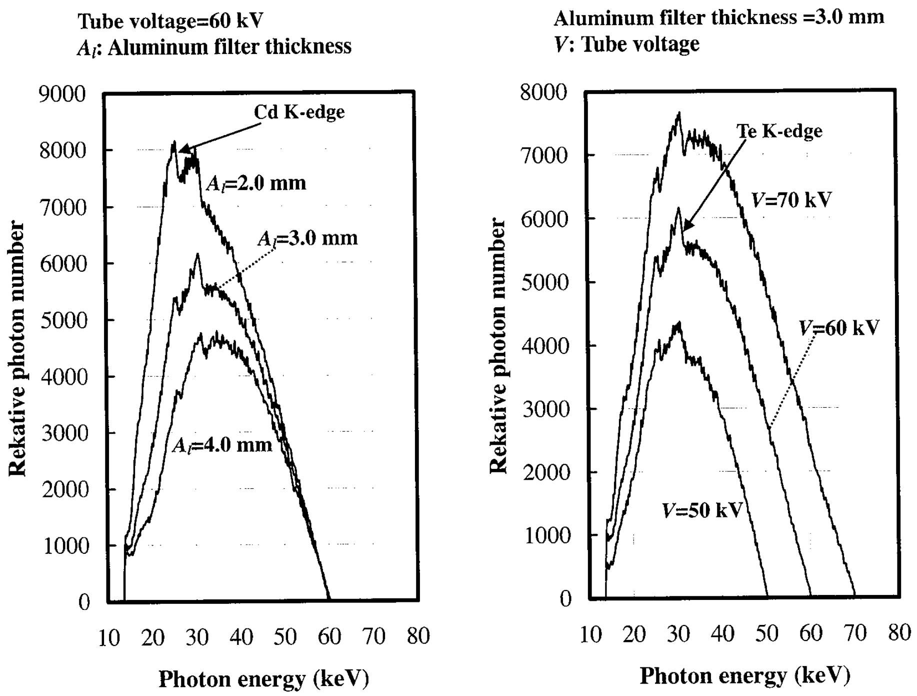

Fig. 3. X-ray spectra from the generator (a) according to changes in the aluminum filter thickness at a constant tube voltage of 60 kV and (b) changes in the tube voltage using a 3.0-mm-thick aluminum filter.

5. Conclusions and Outlook

We developed the first generation x-ray CT system with a high sensitive CdTe detector and performed biomedical tomography. In this CT system at a constant tube voltage and a tube current, the x-ray exposure time for obtaining one tomogram increases with decreases in the pitches of the translation and rotation.

This CdTe detector used in this experiment detects x-ray photons with energies from 5 to 150 keV, and various biomedical objects can be imaged using optimum x-ray spectra controlled by the tube voltage and the filter thickness. At a constant tube voltage, the exposure time decreases according to increases in the tube current and to decreases in the filter thickness.

This x-ray CT system utilizes the CdTe detector, and x-ray spectra can be measured using the detector in conjunction with a charge amplifier, a linear amplifier, and a MCA. Therefore, we have developed a photon counting and an x-ray fluorescence CT systems to perform molecular imaging for cancer diagnosis utilizing a DDS.

Fig. 4. Tomogram of a piece of wood.

Fig. 5. Tomogram of an apple.

Fig. 6. Tomogram of a fish.

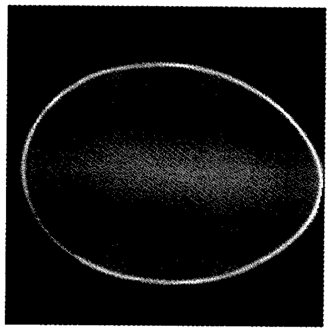

Fig. 7. Tomogram of a raw egg.

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References

1. E. Sato, M. Sagae, E. Tanaka, Y. Hayasi, R. Germer, H. Mori, T. Kawai, T. Ichimaru, S. Sato, K. Takayama and H. Ido, "Quasi-monochromatic flash x-ray generator utilizing a disk-cathode molybdenum tube," *Jpn. J. Appl. Phys.*, **43**, 7324-7328 (2004).
2. E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Ichimaru, S. Sato, K. Takayama and H. Ido, "Compact monochromatic flash x-ray generator utilizing a disk-cathode molybdenum tube," *Med. Phys.*, **32**, 49-54 (2005).
3. E. Sato, Y. Hayasi, R. Germer, E. Tanaka, H. Mori, T. Kawai, T. Ichimaru, S. Sato, K. Takayama and H. Ido, "Sharp characteristic x-ray irradiation from weakly ionized linear plasma," *J. Electron Spectrosc. Relat. Phenom.*, **137-140**, 713-

720 (2004).

4. E. Sato, Y. Hayasi, K. Kimura, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, S. Sato, K. Takayama, J. Onagawa and H. Ido, "Enhanced K-edge angiography utilizing tantalum plasma x-ray generator in conjunction with gadolium-based contrast media," *Jpn. J. Appl. Phys.*, **44**, 8716-8721 (2005).
5. E. Sato, Y. Hayasi, R. Germer, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, S. Sato, K. Takayama and J. Onagawa, "X-ray spectra from weakly ionized linear copper plasma," *Jpn. J. Appl. Phys.*, **45**, 5301-5306 (2006).
6. E. Sato, Y. Hayasi, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, S. Sato, K. Takayama, J. Onagawa and H. Ido, "K-edge angiography utilizing a tungsten plasma x-ray generator in conjunction with gadolinium-based contrast media," *Rad. Phys. Chem.*, **75**, 1841-1849 (2006).
7. M. Sagae, E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, S. Sato, K. Takayama, J. Onagawa and H. Ido, "Intense clean characteristic flash x-ray irradiation from an evaporating molybdenum diode," *Opt. Eng.*, **46**, 026502-1-7 (2007).
8. E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, S. Sato, K. Takayama and J. Onagawa, "Characteristic x-ray generator utilizing angle dependence of bremsstrahlung x-ray distribution," *Jpn. J. Appl. Phys.*, **45**, 2845-2849 (2006).
9. E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, M. Izumisawa, K. Takahashi, S. Sato, T. Ichimaru and K. Takayama, "Super-characteristic x-ray generator utilizing a pipe and rod target," *SPIE*, **6319**, 63190Q-1-6 (2006).
10. E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Ichimaru, S. Sato, K. Takayama and H. Ido, "Demonstration of enhanced K-edge angiography using a cerium target x-ray generator," *Med. Phys*, **31**, 3017-3021 (2004).
11. E. Sato, A. Yamadera, E. Tanaka, H. Mori, T. Kawai, F. Ito, T. Inoue, A. Ogawa, S. Sato, K. Takayama, J. Onagawa and H. Ido, "X-ray spectra from a cerium target and their application to cone beam K-edge angiography," *Opt. Eng.*, **44**, 096502-1-6 (2005).
12. E. Sato, E. Tanaka, H. Mori, T. Kawai, T. Inoue, A. Ogawa, A. Yamadera, S. Sato, F. Ito, K. Takayama, J. Onagawa and H. Ido, "Variations in cerium x-ray spectra and enhanced K-edge angiography," *Jpn. J. Appl. Phys.*, **44**, 8204-8209 (2005).