P－01

Measurements of energy dependence in image detectors using monochromatized X-ray

Tatsuya Fujisaki[1], Katsuyuki Nishimura[1], Saori Iijima[2], Shinji Abe[1],
Norio Sekine[1], Yoshikazu Takahashi[1], Hidetoshi Saitoh[3], Kazuyuki Hyodo[4]

[1] Department of Radiological Sciences, Ibaraki Prefectural University of Health Sciences
[2] Department of Radiology, Tsukuba Medical Center Hospital
[3] School of Radiologic Sciences, Tokyo Metropolitan University of Health Sciences
[4] Institute of Material Structure Sciences, High energy accelerator research organization

INTRODUCTION

In the computed radiographic (CR) system, a photostimulable phosphor plate (imaging plate[1], IP) is used as an image detector. The system has the properties of high sensitivity and wide dynamic range which cannot be obtained with an X-ray film. Although research of the image characteristic using for the radiodiagnosis have been carried out, so far there has been little work on the energy characteristics. White X-rays, which arise from medical X-ray tubes, can be used to examine performance and characteristics of image detectors as a while. However, it is difficult to evaluate the energy dependence of these characteristics with white X-rays, since they have a continuous X-ray energy spectrum. Then monochromatic X-rays should be used for this kind of evaluation.

We have developed a practical spectroscopic system using conventional X-rays that arise from a medical X-ray tube were monochromatized with Si crystal[2]. Using the developed the spectroscopic system, the relative sensitivity and the characteristic curve were measured in order to evaluating energy characteristics for some image detectors.

METHODS

A. Development of spectroscopic system

As a diffraction crystal, Si was used in the developed spectroscopic system (**Fig.1**) because high purity single crystal is easily available. The diffraction lattice plane index (3,1,1) was selected because the incident angle is larger than (1,1,1), and the monochromatization was done by symmetrical reflection. The positioning was done on a stage manipulated in 2 axial directions (Sigma Koki Co.,LTS-400X and CRS-120) with the setting accuracy of 0.05 deg for the translation axis and 0.06 mm for the translation distance. It was placed on an optical frame (Sigma Koki Co., Σ-11-(7)).

White X-rays were generated by an inverter high voltage X-ray apparatus (Hitachi Medical

Co., DHF-155H) and X-ray tube (Hitachi Medical Co., UH-6GE-31T; focus size 1.0 mm×1.0 mm, inherent filtration 1.0 mmAl + addition filtration 0.8 mmAl). The X-rays were collimated by two Pb plates (5 mm thick) which had a pinhole opening 5 mm in diameter. Since the developed spectroscopic system was constructed with the low atomic number materials except for the Pb collimators, it was considered that almost no fluorescent X-rays were generated.

B. Measurements of energy dependence

The relative sensitivity of IP that is one of the image detectors was evaluated from monochromatized X-ray absorption rate, which was calculated from relative exposure and intensity of photostimulated light (pixel value). IP was inserted in the shading bag that could regard the X-ray absorption. The ST-V type IP was used. A computed radiographic system (Fuji Medical Systems Co., FCR9000-HQ) employed in our study. The image data on exposed IP was acquired the CR system. The exposure data recognizer (EDR) function which decided reading condition was canceled, and it was fixed in S (sensitivity) = 2000 and L (latitude) = 4.0. Logarithmic amplification was performed prior to analog-to-digital (A/D) conversion. For image data analysis, the digital data was converted into the DICOM format, and it was transferred to the UNIX computer (Silicon Graphics Inc., Indigo2). The measurement of the pixel value was carried out by the image processing software (AJS Co., Dr.View4.0). Matrix size in the image processing software was 2000×2500 pixel and 10 bit, and the mean pixel value were obtained by averaging pixel values over 400 pixels in central exposure area of 20×20 pixels.

The measurement of the digital characteristic curve was performed the time scale method.

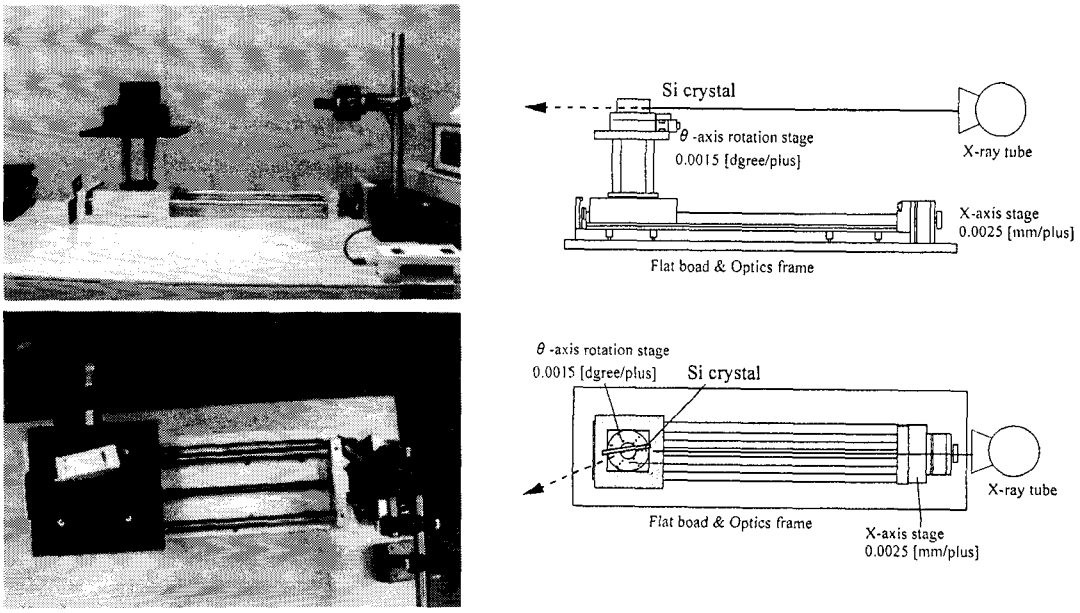

Fig.1 The spectroscopic system.

RESULTS AND DISCUSSION

The spectroscopic system, composed of high-precision stages, Si(3,1,1) diffraction crystal and X-ray tube, was developed which provided monochromatization from 0.15 to 1.4 keV FWHM in the 32 to 70 keV energy region of diagnostic radiography[1]. Spectra of 80 kV white X-rays and monochromatized X-rays are shown in **Fig.2.** The peak count of monochromatized X-rays was proportional to the count of the white X-ray spectrum at the corresponding X-ray energy. The increase of FWHM of the spectroscopic system in proportion to the X-ray energy was attributed to the decrease in the incident angles to the crystal. The value of FWHM at 32 keV agreed well with that measured by synchrotron radiation[3]. The intensity of monochromatized X-rays at 50 keV was about 1 % of the total intensity of the white X-rays[1]. Thus, an X-ray tube current, 80 times more than usual, is necessary to supply monochromatized X-rays with the same intensity as white X-rays.

X-ray absorption rate of IP for the X-ray energy, and the pixel value per incident and absorbed photon to IP were obtained from the measurement of the relative sensitivity. It was shown that the X-ray absorption characteristics of IP changed as well as the mass attenuation coefficient of barium, and IP output per absorbed photon increased with the X-ray energy except for K absorption edge of barium respectively. The barium atom that is mainly included in the phosphor explained the reason for the rapid change of X-ray absorption rate. It was found that halogen and Eu^{2+} ion, which are other constituent element of IP, did not almost depend on the X-ray absorption characteristics. **Figure 3** shows the digital characteristic curves of the CR. It was shown that IP had the wide exposure latitude compared to X-ray film. In the radiodiagnosis region, the gradient change of the characteristic curve for the X-ray energy was not found. These results show that IP can accurately detect the X-ray absorption difference in radiography, and it shown to be usable for the radiation measurement.

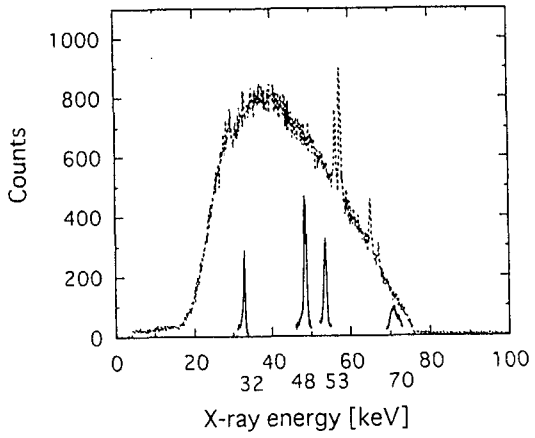

Fig.2 Spectra of 80 kV white X-ray and 32, 48, 53 and 70 keV monochromatized X-rays.

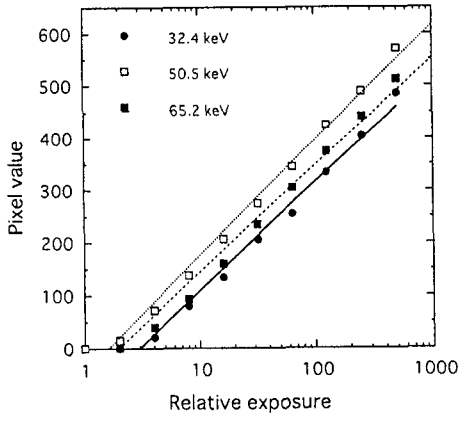

Fig.3 The digital characteristic curves of the CR.

CONCLUSION

The spectroscopic system was developed in which the white X-rays generated from a medical X-ray tube were monochromatized with Si crystal. Then, the energy characteristics of imaging detectors were evaluated using a developed spectroscopic system.

References

1) T. Fujisaki, K. Nishimura, S. Iijima, et al: Development of X-ray spectroscopic system using medical X-ray tube, Jpn J Med Phys 19, 1999 (in press)

2) M. Sonoda, M. Takano, J. Miyahata, et al: Computed radiography utilizing scanning laser stimulated luminescence, Radiology 148; 883-888, 1983

3) H. Shiwaku, K. Hyodo and M. Ando: X-ray characterization of lapped surfaces of Si and Ge single crystals at 33.17 keV, Jpn J Applied Physics 30: 2065-2067, 1991