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# SOME DIAGNOSTIC X-RAY SPECTRA AND EXPOSURE ATTENUATION CURVES MEASURED USING CdZnTe DETECTOR

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## INTRODUCTION

By a Ge detector, we cannot measure directly the X-ray spectra produced at a large current like diagnostic factors. We have attempted to measure directly diagnostic, mammographic and computed tomography (CT) X-ray spectra produced by each X-ray unit with the low-efficiency CdZnTe(CZT) detector. Since detected spectra do not coincide with the true photon spectra, the correction by the stripping procedure[1)] is applied. This procedure has been determined by an evaluation of spurious effects (K-escape, coherent scattering, incoherent (Compton) scattering) and incomplete charge collection obtained using the Monte Carlo method and trial and error method respectively.

## METHOD

### 1. Direct measurement of diagnostic X-ray spectra

We have attempted to perform the direct measurement of diagnostic X-ray spectra using Ge and CZT detectors. Photon spectra penetrated through an object(1mmAl~6mmAl) produced by a single-phase 2-pulse diagnostic X-ray unit(SHIMADZU UD150L-5 and CIRCLEX 1/2U13CN-25)driven at 50-100kV and a few mA have been analyzed[2)]. Each exposure attenuation curve for 50~100kV is calculated and is compared with the curve measured by an ionization chamber(VICTOREEN RADCON MODEL 500 and 550-4 TYPE 0.1MA PROBE).

### 2. Direct measurement of mammographic X-ray spectra

We have attempted to perform the direct measurement of mammographic X-ray spectra using a 25 $\mu$ m-collimator and the CZT detector. Photon spectra penetrated through 0.03mm Mo or 0.025mm Rh filter and object(0.1mmAl~1.2mmAl) produced by a mammographic X-ray unit(GE SENOGRAPHE DMR) at 25~32kV and 80mAs have been analyzed[3)]. Each exposure attenuation curve for 25~32kV is calculated and is compared with the curve measured by an ionization chamber(PTW-FREIBURG TYPE 23344).

### 3. Direct measurement of computed tomography (CT) X-ray spectra

We have attempted to perform the direct measurement of computed tomography (CT) X-ray spectra using the CZT detector. Photon spectra penetrated through object(1mmAl~8mmAl) produced by a CT scanner(HITACHI LSCT) driven at 120kV and 3mA have been analyzed[4)]. The exposure attenuation curve for 120kV and 3mA is calculated and is compared with the curve measured by an ionization chamber(VICTOREEN RADCON MODEL 500 and 550-4 TYPE 0.1MA PROBE).

## RESULTS AND DISCUSSION

The comparison of corrected diagnostic X-ray spectra at (a)70kV and (b)100kV for Ge and CZT detectors are shown in Figure 1. The corrected spectra at (a)70kV and (b)100kV for the CZT detector coincide with those for the Ge detector. Each exposure attenuation curve for (a)70kV and (b)100kV is calculated and is compared with the curve measured by the ionization chamber in Figure 2. The obtained results with the CZT detector agree with those obtained by the ionization chamber.

The comparison of corrected mammographic X-ray spectra at 25kV for Ge and CZT detectors are shown in Figure 3. The corrected spectrum(a) at 25kV for the CZT detector coincides with the spectral data[5](b)for the Ge detector published by Bureau of Radiological Health(BRH). Each exposure attenuation curve for (a)25kV and (b)28kV is calculated and is compared with the curve measured by the ionization chamber in Figure 4. The obtained curves with the CZT detector agree with those obtained by the ionization chamber.

The comparison of directly measured (at 120kV, 3mA) and corrected primary X-ray spectra of CT scanner made by HITACHI Co. is shown in Figure 5(a). In Figure 5(a) the dotted line is the direct measured spectrum and the solid line is the spectrum corrected by using equation (4).

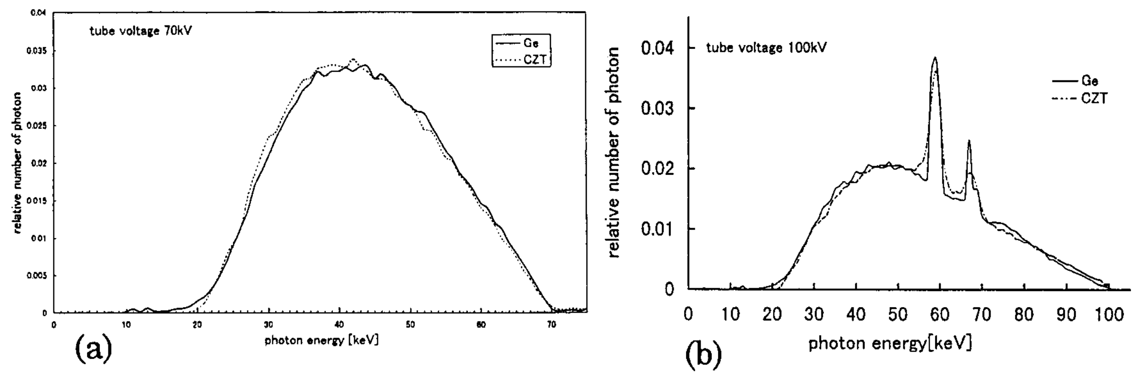


**Figure 1 Comparison of corrected diagnostic X-ray spectra at (a)70kV and (b)100kV for Ge and CZT detectors.**

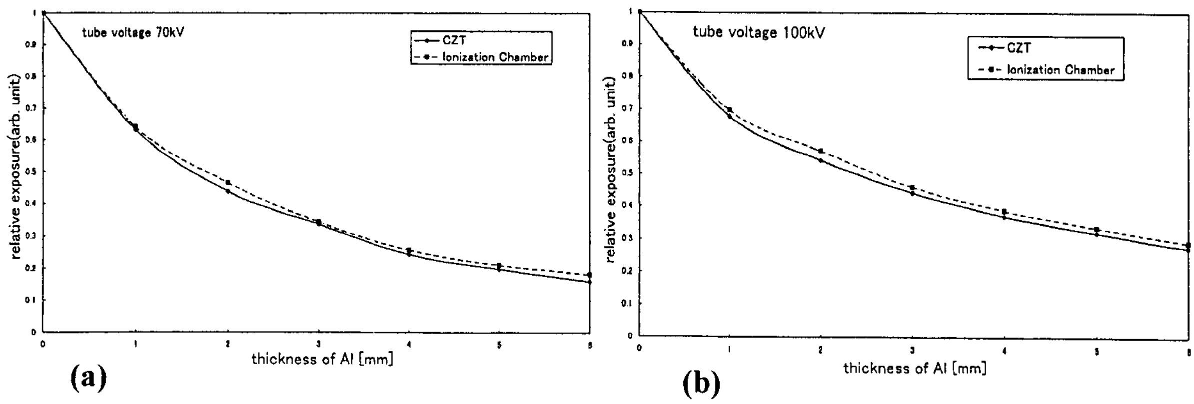


**Figure 2 Comparison of exposure attenuation curves obtained from the CZT spectra and the ionization chamber at (a)70kV and (b)100kV.**

The corrected spectrum obtained with the CZT detector roughly agrees with CT X-ray spectral data[6] obtained using a Ge detector published by BRH shown in Figure 5(b).

The exposure attenuation curve at 120kV and 3mA is calculated and is compared with the curve measured by the ionization chamber in Figure 6. The curve obtained with the CZT detector agrees with the curve obtained by the ionization chamber.

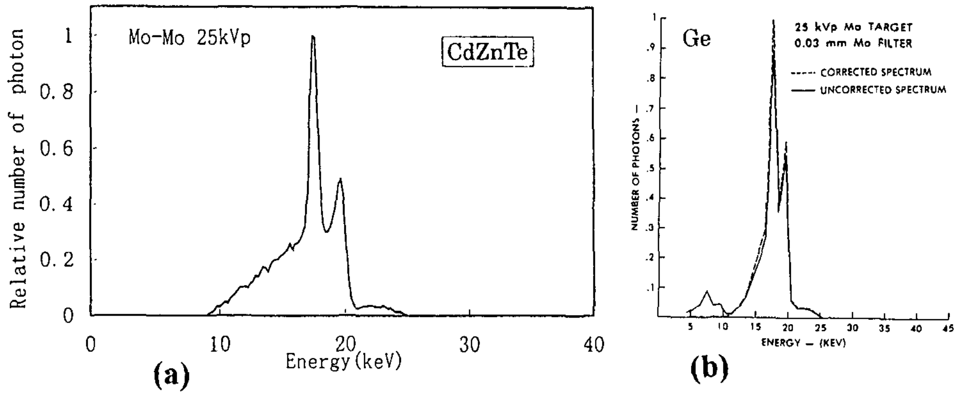


**Figure 3 Comparison of corrected mammographic X-ray spectra at 25kV for CZT(a) and Ge(b) detectors.**

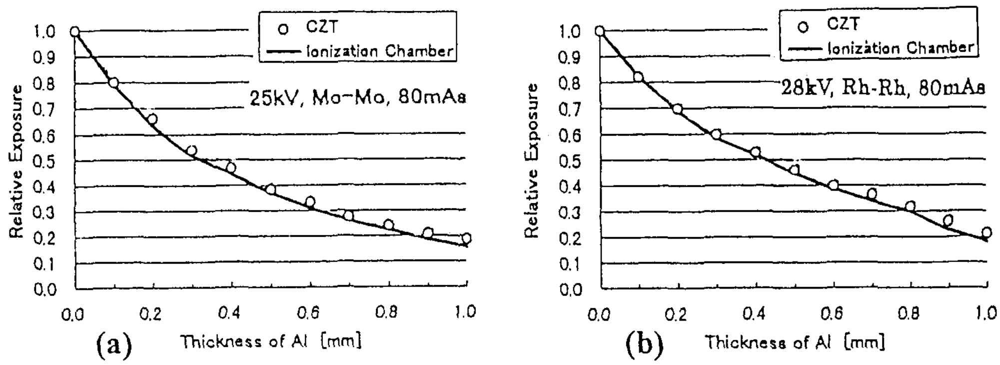


**Figure 4 Comparison of exposure attenuation curves obtained from the CZT spectra and the ionization chamber at (a)25kV and (b)28kV.**

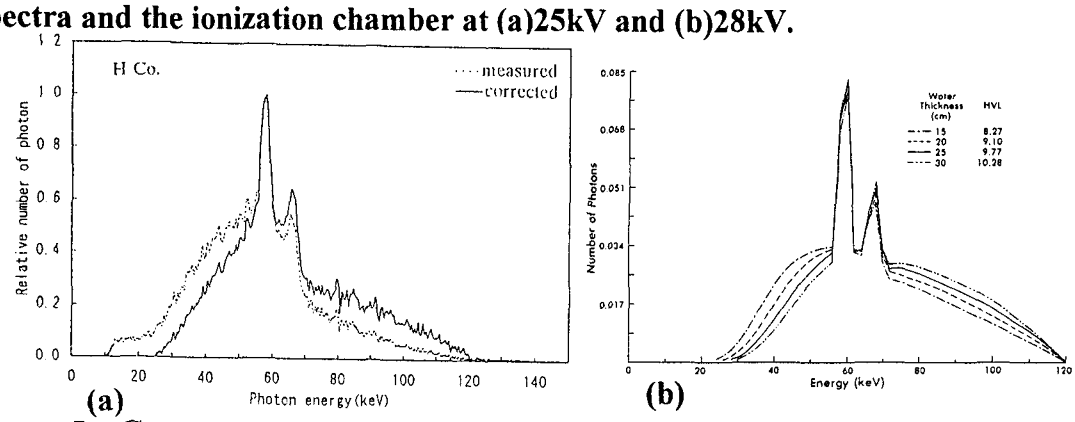


**Figure 5 Comparison of photon spectra measured and corrected(a) with CT X-ray spectral data[6] of BRH(b).**

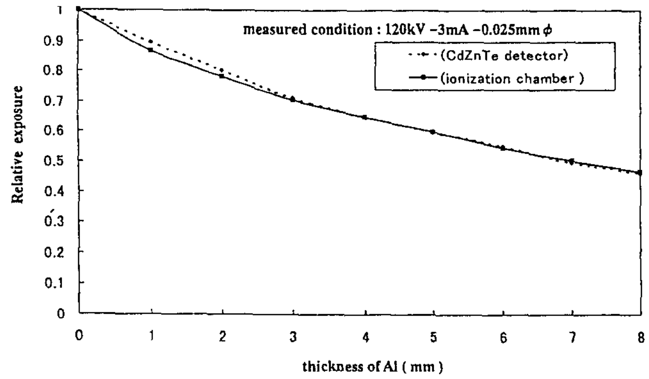


**Figure 6 Comparison of exposure attenuation curves obtained from the CZT spectra and the ionization chamber at 120kV and 3mA.**

## CONCLUSION

We have attempted to perform the direct measurement of X-ray spectra using the low-efficiency CZT detector, which have been developed recently. Photon spectra produced by a single-phase 2-pulse diagnostic X-ray unit driven at 50-100kV and a few mA, mammographic X-ray unit at 25-32kV and 80mAs and X-ray CT scanner at 120kV and 3mA have been analyzed. Since detected spectra do not coincide with the true photon spectra, a correction by the stripping procedure is applied. This procedure has been determined by an evaluation of spurious effects (K-escape, coherent scattering, incoherent(Compton) scattering) and incomplete charge collection obtained using the Monte Carlo method and trial and error method respectively. The results obtained using the CZT detector agree with X-ray spectral data published by BRH, which was measured by using a Ge detector and agree with those obtained by an ionization chamber. Therefore we think that the CZT detector is able to use for quality control and quality assurance of some diagnostic X-ray units.

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## MONTE CARLO SIMULATION

Based on the basic idea of the detector, various combination of parameters such as optical properties of crystal and joint material, placement of optical reflector, detector unit geometry should be examined by computer simulation. As a preliminary step, however, we need to check if the simulator correctly represents the phenomena occurring in practical detectors. Thus the outputs of the simulator were compared with the experimental data obtained with several prototype detectors[1].

In this paper, we show the comparison in the case of the detector unit shown in Fig. 1. Each crystal block in the prototype detector has the dimension of 4 mm (row) x 4 mm (column) x 6 mm (depth) and has 4 mm slit in the top stage. In the experiment a 0.1 mCi Cs-137 (662 keV) point source was placed at the distance of 18 mm above the detector unit. Assuming the same situation, Monte Carlo simulation for optical photon migration in crystal blocks was performed. Simulation condition is as follows:

- Total number of interaction in detector unit: 7,000.
- Depth dependent probability of interaction in crystal: An exponential function with the attenuation coefficient, $0.54cm^{-1}$ at 662keV.
- Optical photon output: 1,086 photons/interaction. (10% of GSO crystal light yield (16,400 photons/MeV) at 662keV. This is approximately equivalent to the condition of 10% quantum efficiency at PMT.)
- Reflection between crystal and air gap: Fresnel reflection based on the refractive indices of material at boundary. (Refractive index of GSO is 1.85. 10% surface roughness is assumed, namely, for 10% optical photons, an incident angle is changed at random.)
- Reflection on slit surface: Fresnel reflection on completely rough surface.
- Reflection on crystal boundary wrapped by PTFE tape: Lambartian reflection, or completely diffuse reflection (reflectance of 0.98).

Fig. 3 shows the histograms of X, Y values obtained by the experiment and Monte Carlo simulation. Fig. 4 shows a comparison in energy spectrum. Note that the simulation results have the energy distribution of photo peak only because we neglected the scatter in the detector. In both figures, the simulation results are similar to the experimental results.

The similarity of these results were numerically evaluated with the following items.

In the X-Y histogram,

(i) distance between the origin and the center of each cluster

(ii) spread of each cluster which is defined by the mean standard deviation in each cluster.

In the energy spectra,

(iii) relative position of photo peaks of three stages (normalized by the value of stage 1)

(iv) relative number of interaction in each stage (normalized by the value of stage 3).

These evaluated values are listed on Table 1. Most values in the experiment and the simulation show relatively good agreement. However, slight discrepancy is found in some aspects. In the X-Y histogram, the separation between clusters in the simulation is slightly better than that in the experiment. In the energy spectrum, the difference between stage-2 and stage-3 in the simulation is less than that in the experiment. Consequently, fine tuning of the parameters is necessary for better agreement.

## CONCLUSION

In comparison between the experiment and Monte Carlo simulation, similar results have been obtained and the basic performance of the simulator has been validated. Hereafter we will examine many other combination of simulation parameters to find the optimum DOI detector configuration.

## REFERENCE

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