HIGH-RESOLUTION SCINTICAMERA BASED ON DELAY-LINE TIME CONVERSION

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A new scinticamera that has almost ideal position arithmetics and has been used experimentally has already been reported (*1*,*2*). The position computer is based on the position-to-time conversion as follows: the signals from the photomultiplier (PM) tubes are connected to two delay lines, one for the x-axis and the other for the y-axis, so that the delay times for each PM signal are proportional to the x- and y-coordinate of the PM, and the output pulses are doubly clipped to form bipolar pulses. The zero-crossing time of the pulses is detected and then converted to the "position signal."

In the previous work (*2*), a comparison was made between the delay-line camera and the conventional Anger camera using the same detector; significantly better spatial resolution was obtained with the delay-line camera. In the present study, further improvement in spatial resolution and in other camera performance was achieved by improving the electronic system and the image detector.

APPARATUS

The detecting head consists of a NaI(Tl) crystal (Harshaw, 292 mm diam × 12.7 mm thick) and 19 PM tubes (RCA-4524). The center-to-center spacing of adjacent PM tubes is 79 mm. Various shapes of light guides were tested and finally a Lucite plate 416 mm in diam and 20 mm thick was used.

The electronic system is similar to that in the previous work (*2*), but the entire system was newly reconstructed with the following improvements. First, the time response of the circuit was improved by incorporating digital integrating circuits (IC). Second, the total delay time of the conversion delay lines was shortened from 3.8 μsec to 2 μsec to reduce resolving time. This leads to the conversion factors of 5.0 and 5.7 nsec/mm for the x- and y-axes, respectively. The clipping time of the bipolar shaping was also reduced in proportion to the conversion factor. Finally, to prevent incorrect computation and display due to pulse pile-up encountered at high counting rate, two additional circuits were provided. One inhibits the position computation if a pulse arrives within 3 μsec after the preceding pulse without respect to the amplitude of the preceding pulse, and the other stops displaying the position signal when the succeeding pulse occurs before the displaying finishes.

The time required to compute the position is less than 3 μsec (depending on the location of scintillation), and the display period is 1.5 μsec. Thus the system resolving time is 4.5 μsec at maximum.

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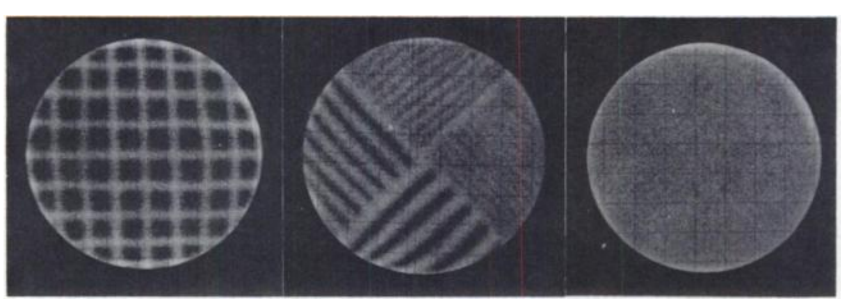

A B C

FIG. 1. Scintiphotos obtained with ^{57}Co illustrating linearity (A), spatial resolution (B), and uniformity (C). In A grid spacing is 30 mm and slit width is 3 mm. In B both spacing and width of bars are 12, 9, 6, and 4.5 mm. In C total dot counts are 10^6.

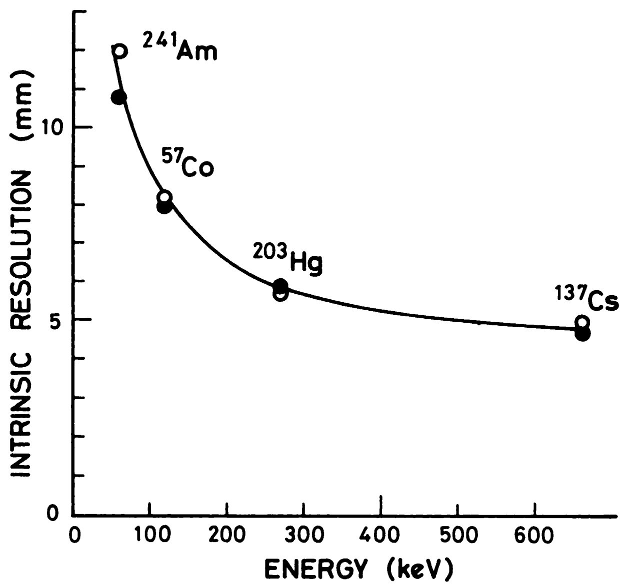

FIG. 2. Resolution distance (FWHM) at crystal center as function of photon energy. Solid and open circles are resolution for x- and y-axes, respectively.

RESULTS

A scintiphoto illustrating the linearity is shown in Fig. 1A. This photograph was obtained by placing a lead grid phantom in front of the crystal window and then irradiating it uniformly with a ^{57}Co source. The width of the slit was 3 mm, and the grid spacing was 30 mm. Figure 1B shows the resolving power for ^{57}Co obtained with a lead bar phantom. Both the width and spacing of the bars are 12, 9, 6, and 4.5 mm. The total dot counts are 10^6. To determine the intrinsic resolution quantitatively, narrow-beam response functions were obtained by pulse-height analysis of the position signal. Figure 2 shows the FWHM of the response at the center of the crystal as a function of photon energy. The value of FWHM for ^{57}Co (120 keV) was 8.0 mm. The uniformity of sensitivity was within $\pm 10\%$. Figure 1C shows the uniformity for ^{57}Co.

One problem in shortening the system resolving time is the degradation of spatial resolution due to the statistical fluctuation of pulse rise time. This effect was examined experimentally by changing the delay time of the conversion delay lines. The degradation of resolution amounted to only a few percent for ^{57}Co when the delay time of the conversion delay line was decreased to 2 μsec from 3.8 μsec. With 2 μsec conversion delay line the system works satisfactorily at a gross counting rate of up to 1.5×10^5 cps for ^{57}Co.

One distinctive feature of the delay-line camera is the fact that a simple, flat Lucite plate can be used as the light guide. This results in high light collection efficiency and therefore good spatial resolution, while good picture linearity and uniformity are realized by modifying the wave form of the bipolar pulse.

The energy resolution is also improved. This is particularly important for rejecting the counts due to photons scattered in a thick subject by pulse-height analysis. The energy resolution (FWHM) was 13–14% for ^{57}Co when the crystal was irradiated uniformly.

Thus it can be concluded that the delay-line camera has fairly good intrinsic spatial resolution together with good energy resolution, and therefore it will be useful in high-resolution scintigraphy if a suitable fine collimator is provided.

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