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A Study on the Portable Nuclear Survey System with Imaging Capability

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Abstract

A portable gamma camera that has been developed for the radiation monitoring in nuclear facilities is composed of a combined CCD (Charge-Coupled Devices) and a gamma imaging system that produces accurate two-dimensional images by the gamma ray of emitting from objects through the superimposition of visible image. This system can quickly determine the location and measure the radioactivity of radiation source from long distance because it produces real-time color of gamma ray image and a conventional black and white CCD picture. The ability to operate at a safe distances from source is essential practical nuclear survey such as high level radiation field and other application where significant dose savings is needed. In this paper, a prototype gamma camera system has been developed and tested for the characteristic analysis at laboratory as well as at other area having high-level radiation field. Through preliminary test for producing image from gamma ray sources with the energies between 140 keV and 662 keV, this developed prototype system be shown that spatial resolution defined as a function of FWHM (Full With Half Maximum) is 9.6 mm with intrinsic efficiency of 2.7 % at a distance of 5 cm source, 10 μCi ^{137}Cs.

1. Introduction

Modern nuclear monitoring system that is currently used in various nuclear facilities is able to measure the value of radiation intensity, but it is impossible to give directional information containing the location and distribution of radiation sources.

The portable gamma camera, which has been developed by R.H. Redus in 1992, is useful for the gamma imaging application in the nuclear facilities because this system doesn’t only allow the operator to easily visualize the distribution of radiation source but also can distinguish two sources having different energies and radioactivities through getting real-time information of gamma image. [1~4] Therefore, this system overcomes the disadvantages of other instruments that can give two-dimensional information of the gamma image. One of the remarkable characteristics at this system is its mass and its size, which make it very ease to handle, so this system can be controlled by robot at a remote or safety area from the high-level radiation area that operator can't go directly. Especially, this system is of great interest in nuclear facilities for applications such as the preparation of an intervention in a hot cell or the control in the decommissioning of nuclear facilities. The nuclear survey system is divided by gamma imaging system and visual instrument called as CCD camera that makes the operator to easily measure the distribution of gamma image. The gamma imaging system, which is based on scintillation detector, position sensitive photo-multiplier (PSPMT), the electric circuit and pinhole collimator. We have designed pinhole collimator and developed the integrated system of gamma camera and CCD camera for getting the perfect two-dimensional gamma images. Finally, it has been tested for characteristic analysis at laboratory.

2. System Design of Portable Gamma Camera

As described above, our portable nuclear survey system is composed of the CCD camera and gamma imaging system. A schematic diagram and photography are shown in Figure. 1 and 2.

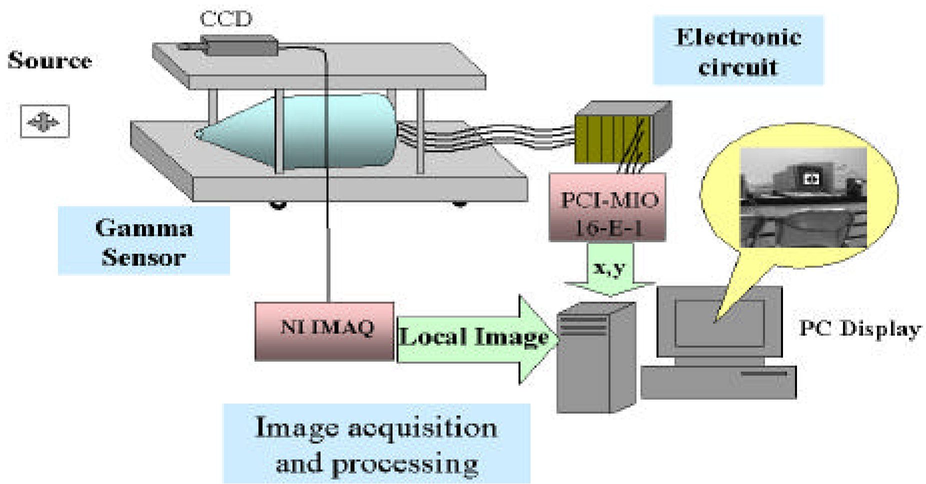

Figure. 1 A schematic diagram of gamma camera system

Figure. 2 The developed gamma camera system

The gamma rays emitting from the source interact with the scintillator, which converts the gamma rays into the visible light and then are detected as pulse signal through the photomultiplier. Pulse signal is amplified and interaction position is calculated through electric circuit used for getting the information of gamma rays distribution. Data acquisition board and computer display the exact position of the interaction with the gamma rays and the scintillator.

A. Shield and collimator

Shield is important for reducing noise signal by background radioactivity. Detector and PSPMT are enclosed by lead and stainless steel. The lead thickness of 2 cm for a length of 25 cm is selected, which can shield the half value of ^{40}K. We have designed the shield that could be separated by two parts for ease decontamination (see Figures 3). Pinhole collimator is in tungsten. [5] The stainless thickness of 5 mm for supporting the lead weight is determined.

The focal length, the distance form the pinhole plane to the scintillation plane, is 108.8 mm and field of view of the collimator is 42^0. Collimator is mounted on the front of the lead shield. (See Figure. 3) In order to exchange easily from one to other collimator, The collimator is divided by two parts that are lead ring and tungsten.

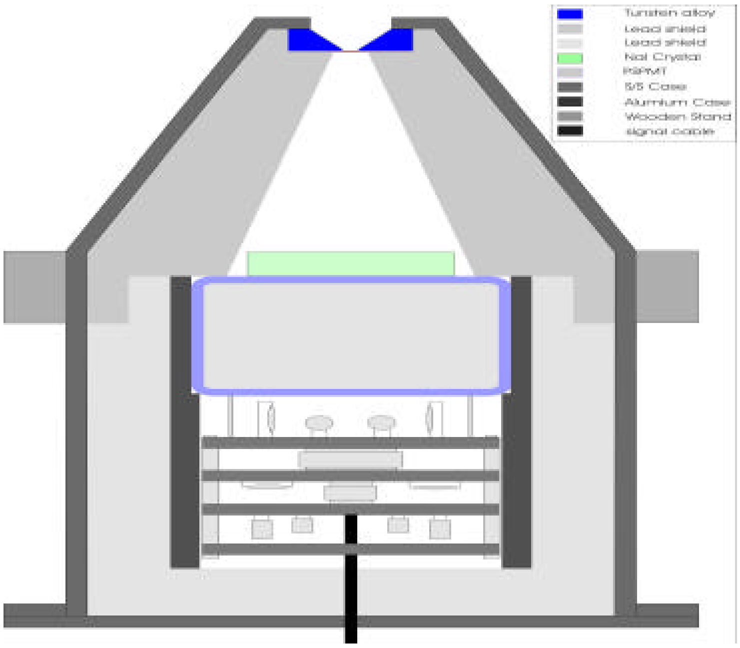

Figure. 3 The designed gamma sensor

B. Detector

NaI(Tl), CsI(Tl), and BGO were chosen by consideration of economic efficiency and simpleness of handling. The unique characteristics of this gamma camera are usage of the PSPMT made in Hamamatsu Photonics. [6] The PSPMT, which is consisted of only one photomultiplier, has capability that the position and energy of the incident gamma ray can be computed. As one can measure energy and position of incident radioisotope, multi-source containing different energies can be separated.

C. Data acquisition system and display

Image process consists of data acquisition and display. In this system, NI data acquisition board (DAQ) is used. We can get the position and energy information of gamma rays through DAQ and get visible information from CCD and then finally obtain superimposing gamma image thorough combining gamma image into CCD image. The CCD image is displayed as gray scale, while gamma image is displayed in pseudo-color.

3. Results and Discussion

In order to measure the spatial resolution and intrinsic efficiency, we measured some images of isotropic sources located between 5 cm and 1 m from detector plane of camera. Using the pinhole collimator and a 42^0 field of view, the measured spatial resolution defined as a function of FWHM (Full With at Half Maximum) is 9.6 mm with intrinsic efficiency of 2.7 % at 5 cm distance from source and detector plane when is measured by 10 μCi ^{137}Cs. Figures 4,5 are shown in this results.

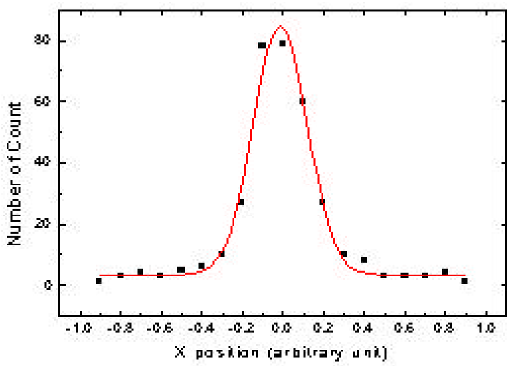

Figure. 4 Spatial resolution

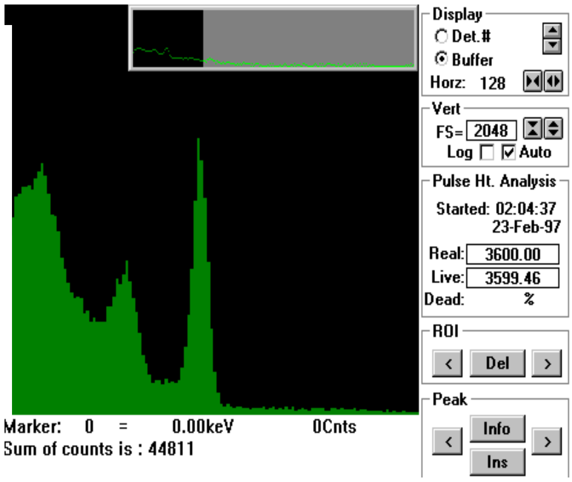

Figure. 5 Energy spectrums of ^{137}Cs

Energy resolution of this system is also 12 % at the same condition. Figure. 6 show a combined CCD and gamma image of this source of 10 mCi at 1 meter.

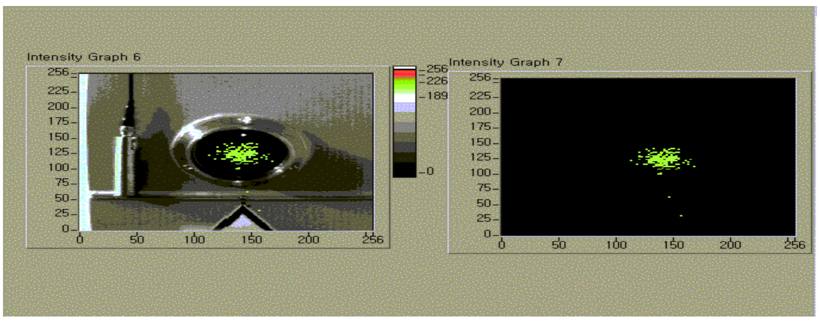

Figure. 6 A combined CCD and gamma image

From this result, it is shown that this system can be used at radiation monitoring in the nuclear facilities.

4. Conclusion

A portable nuclear survey system with imaging capability has been developed, which is composed of a combined CCD camera and a gamma imaging system that produces accurate two-dimensional images of the gamma ray emitting from objects through the superimposition of visible image. This system was tested to analyze its characteristics at gamma ray energy of both 140 keV and 662 keV. The images generated from the close sources were presented and obtained the good quality image through the developed system. We are currently testing the developed system with new collimator for better resolution and efficiency.

5. References

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[6] Specification sheet for type R-2486 Hamamatsu Photonics K.K.Electron Tube Division, Japan

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