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# RADIATION DETECTORS AND THEIR USES

## Proceedings of the 29th Workshop on Radiation Detectors and Their Uses

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# FOREWORD

The 29th workshop on "Radiation Detectors and Their Uses" was held on February 3, 4 and 5, 2015 at the Kobayashi Hall in High Energy Accelerator Research Organization (KEK), Tsukuba, Japan. The workshop was hosted by Radiation Science Center at Applied Research Laboratory (ARL), KEK under the cooperation of the Society of Radiation Science, the affiliate of Japan Society of Applied Physics, and the Technical Committee related to Nuclear Energy of the Institute of Electrical Engineers of Japan (IEEJ). The workshop offers an outstanding opportunity for scientists interested in the fields of radiation physics, radiation detector, radiation measurement, nuclear science, high energy physics and their application to meet and discuss with colleagues from all over the country.

The number of the participants who registered to the workshop was 94. There have been 31 presentations given at the workshop. As the fruits of the workshop, this report is published as the proceedings of "the 29th Workshop on Radiation Detectors and Their Uses". All papers submitted for publication in the proceedings received the peer review process by the independent reviewers. Finally, 11 original papers are published in the proceedings after the review process.

The editors would like to express our great appreciation to the authors who prepared the manuscripts in good earnest and the reviewers who spent their precious time to check the papers.

November, 2015

Shinichi Sasaki
Workshop Program Chair
High Energy Accelerator Research Organization (KEK)

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# STUDY ON HIGH SENSITIVE NEUTRON-DETECTION BY THE SELF-ACTIVATION METHOD WITH A CsI(Tl) SCINTILLATOR

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## 1. Introduction

Recently, we have proposed the self-activation method with iodine-containing scintillators mainly for photo-neutron on-line measurements around an X-ray radiotherapy machine [1]. This method is very high sensitive in principle and suitable to evaluate rather weak neutron fields around an X-ray radiotherapy machine for each patient treatment. The self-activation method is practically advantageous to such routine medical applications because on-line read-out is possible with quasi-real time monitoring as well as its passive detection property.

In our previous work [1], we used an NaI(Tl) scintillator to detect incident neutrons by the activation of iodine [$^{128}$I]. Although NaI(Tl) scintillators are inexpensive and easily available, the activation of sodium [$^{24}$Na] was a source of background. From this standpoint, CsI(Tl) scintillators may be a better choice than NaI(Tl) scintillators for this application. Moreover, CsI(Tl) scintillators are slightly hygroscopic, and the light output is easily read out by a photodiode that is inexpensive and does not need a high-voltage power supply which is usually used for the operation of a photomultiplier. Therefore, it is feasible to develop an inexpensive and rather compact neutron monitoring system using CsI scintillators.

In the present study, an applicability of CsI(Tl) scintillators is examined by neutron detection via iodine activation. The accuracy of $^{128}$I-activity evaluation is also discussed.

## 2. Experimental

A CsI(Tl) detector [2.5 × 2.5 × 2.5 $cm^3$ : HOSHIH CSI-L25] was used in the present work. This detector was irradiated by leakage neutrons from a research reactor UTR-KINKI of Kinki University (thermal output : 1 W) and by neutrons from a Pu-Be source ( $3.7 \times 10^{10}$ Bq ). Similar irradiation was also performed near the primary radiation field of a 10 MV X-ray clinical linac, Valian Clinac 21EX of Kyushu University Hospital. Just after the termination of each irradiation, the self-activation of CsI(Tl) was measured by itself. Pulse height spectra were recorded every one minute and integrated above a fixed discrimination level. The obtained decay curves were fitted with an exponentially-decreasing function and a constant background component. Two cylindrical polyethylene-moderators (13 cm$\phi$ × 13 cm -H, 20 cm$\phi$ × 20 cm -H) and a Cd-sheet ( 1 mm-t) were also used to surround the CsI(Tl).

As shown in Fig. 1, the energy spectrum obtained by the CsI(Tl) itself was significantly dominated by $\beta$ -rays from $^{128}$I in all measurements; the situation was almost identical to that for NaI(Tl). On the other hand, however, contamination of noise component was apparent at low energy region (< 0.5 MeV) due to the use of a photodiode (PD) instead of a photo multiplier (PMT) for NaI(Tl).

Integrated counts were deduced at each sampling period for the energy region higher than 0.5 MeV in order to eliminate noise. And the count-rates (cps) were plotted as a function of elapsed time after the termination of neutron irradiation as indicated in Fig. 2. The decay curve was simply able to be fitted by an exponentially-decreasing function having half-life of 25 min (0.4167 hour) with a constant background component.

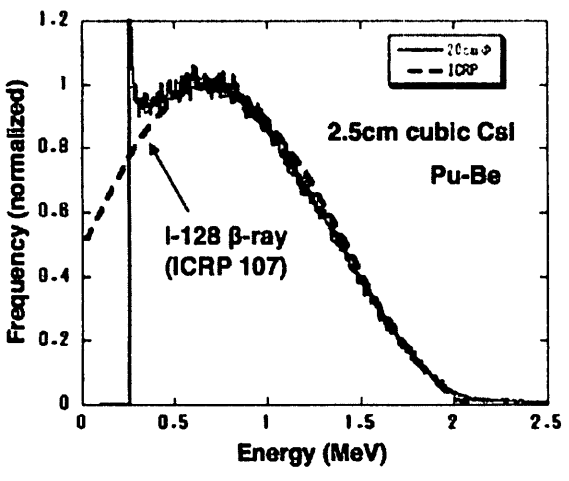


Fig. 1. Energy spectrum obtained by the CsI(Tl) itself.

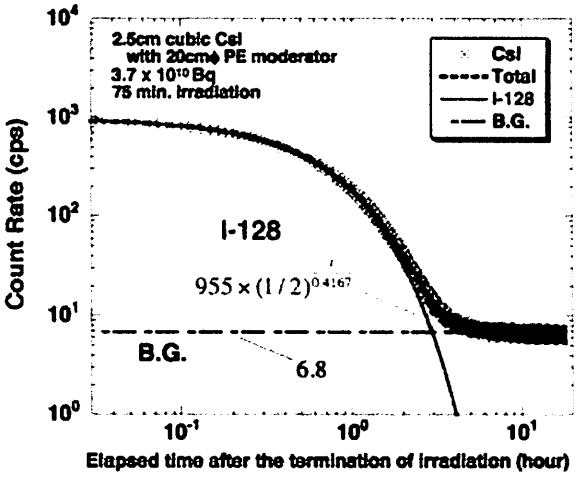


Fig. 2 Decay curve of self-activation of CsI(Tl).

Saturated count-rates ( $R_\infty$ ) were evaluated from the initial count-rates at the elapsed time = 0 ( $R_0$ ) which were obtained by the fitting calculation of decay curves for different size of polyethylene moderators; Fig. 3 displays the results for the 10 MV X-ray clinical linac and for the Pu-Be source. The different responses observed in Fig. 3 imply that neutron energy distributions of these two fields are clearly different. So, the ratio of saturated count-rate for the 20 cm moderator and that for the 13 cm, $R_\infty^{20} / R_\infty^{13}$, was applied to estimate the effective neutron energy of the two fields. The responses for several mono-energetic neutrons were calculated by the PHITS code [2].

For the medical linac field, thermal neutron fluence-rate was evaluated on the basis of the saturated count-rates with/without Cd filter (1.0 mm-t). The result of evaluation gave a value of 2.6 x $10^3$ [n/cm$^2$/s] at 30 cm from the iso-center (out of the primary X-ray irradiation field) when the dose-rate of X-rays at the iso-center was 3 Gy/min.

Figure 4 shows the decay curves observed at the research reactor when several short-time (15 min) irradiations were repeated with different time-intervals.

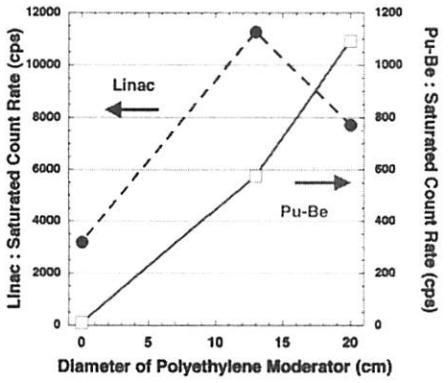


Fig. 3. Saturated count rates for different size moderators.

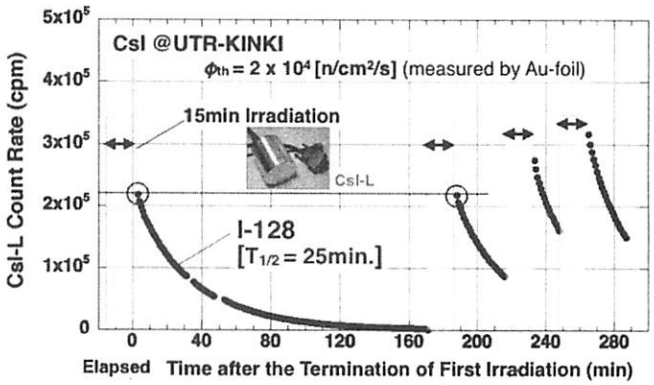


Fig. 4 Decay curves for several repeated irradiations

### 3. Evaluation accuracy of $^{128}$I by a decay-fitting technique

In the self-activation method using iodine-containing scintillators, $^{128}$I component is extracted from the observed decay curve by a mathematical fitting technique based on its inherent half-life of 25 min. In order to examine the evaluation accuracy, actual decay curves of $^{128}$I activity were simulated by a computer program Wolfram with various conditions including some different initial count rates ( $_0$) with a background rates ( $_B$) as well as their counting statistical fluctuations. The data points sampled with every one minute interval and the integrated counts for the same period were fitted by a

non-linear least-squares fitting routine to obtain the value $_0$ as a fitting parameter with its uncertainty ($\sigma_{R_0}$). When $_B$ = 500 cpm is fixed, it has been revealed that relative uncertainty $\sigma_{R_0}/R_0 \leq 0.02$ is achievable for $R_0/R_B \geq 20$ by 20 points fitting procedure from 1 min to 20 min following the termination of neutron irradiation; $\sigma_{R_0}/R_0 \leq 0.01$ is achievable for $R_0/R_B \geq 50$ in the same manner.

## 4. SUMMARY

Neutrons around a research reactor, a Pu-Be source and a clinical linac were successfully detected by the self-activation method with a CsI(Tl) scintillator. The present technique will be useful for the routine on-line evaluation of neutron dose around a clinical linac.

## REFERENCES


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