RADIATION DETECTORS
AND THEIR USES

Proceedings of the 22nd Workshop
on Radiation Detectors and Their Uses

February 5-7, 2008
High Energy Accelerator Research Organization (KEK),
Tsukuba, Ibaraki
JAPAN

Edited by
S. Sasaki, M. Hagiwara, T. Sanami, K. Saito
K. Iijima and H. Tawara
High Energy Accelerator Research Organization

H. Takahashi
University of Tokyo
High Energy Accelerator Research Organization (KEK), 2009

KEK Reports are available from:

High Energy Accelerator Research Organization (KEK)
1-1 Oho, Tsukuba-shi
Ibaraki-ken, 305-0801
JAPAN

Phone: +81-29-864-5137
Fax: +81-29-864-4604
E-mail: irdpub@mail.kek.jp
Internet: http://www.kek.jp
PREFACE

The 22nd workshop on "Radiation Detectors and Their Uses" was held on February 5, 6 and 7, 2008 at the High Energy Accelerator Research Organization (KEK) in Tsukuba, Ibaraki, Japan. The workshop was hosted by the Radiation Science Center, KEK under the cooperation of the Nuclear Engineering Research Laboratory, University of Tokyo and the Society of Radiation Science, the affiliate of Japan Society of Applied Physics. The workshop offers an outstanding opportunity for scientists in the fields of nuclear science, radiation detector, radiation measurement 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 107. 35 presentations were given at the workshop. As the fruits of the workshop, this report was published as the proceedings of "the 22nd Workshop on Radiation Detectors and Their Uses". All papers submitted for publication in the proceedings received the careful review process by independent reviewers. 22 original papers were finally published in the proceedings after the review process.

We 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. We would also express our serious regret for a delay of the publication.

January, 2009

Shinichi Sasaki
Workshop Program Chair
High energy Accelerator Research organization (KEK)
Editors of the proceedings;

Masayuki Hagiwara (KEK)
Toshiya Sanami (KEK)
Kiwamu Saito (KEK)
Kazuhiko Iijima (KEK)
Hiroko Tawara (KEK)
Shinichi Sasaki (KEK)
Hiroyuki Takahashi (Univ. of Tokyo)
# TABLE OF CONTENTS

MATERIAL IDENTIFICATION FROM X-RAY IMAGES MADE BY ENERGY-DIFFERENTIATION TYPE X-RAY LINE SENSOR  ................................................................. 1
   M. Matsumoto, N. Takayama, G. Tamaki and H. Ikebe

ON-LINE EVALUATION OF SPATIAL DOSE-DISTRIBUTION BY USING A 15m-LONG PLASTIC SCINTILLATION-FIBER .................................................. 11
   A. Nohtomi, N. Sugiura, T. Itoh, S. Imanichi, T. Torii and H. Noma

A 500-MHz X-RAY COUNTING SYSTEM WITH A SILICON AVALANCHE PHOTODIODE  ............................................................... 20
   S. Kishimoto

ESTIMATION OF PRECISION OF FUEL DENSITY RATIO MEASURED BY MULTI-SCATTERING TOF NEUTRON SPECTROMETER  ........................................ 30

NON-DESTRUCTIVE RADIOGRAPHY SYSTEM USING LASER-COMPTON X-RAY BEAM  ............................................................. 35
   H. Toyokawa, M. Koike, K. Yamada, H. Kanada and T. Kahihi

LUMINESCENCE PROPERTIES OF GLASS DOSIMETER  .......................................................... 44
   Y. Miyamoto, A. Nishimura, K. Kinoshita, S. Kayama, S. Taniguchi,
   Y. Takei, H. Nanto, T. Kurobora and T. Yamamoto

DEVELOPMENT OF TES MICROCALORIMETER FOR LX-RAY SPECTROSCOPIC ANALYSIS OF TRANSURANIC ELEMENTS  ........................................... 53
   K. Maehata, K. Ueno, K. Nakamura, T. Yasumune, H. Arima,
   K. Ishibashi, T. Umeno, K. Takasaki and K. Tanaka

CHARACTERISTICS OF AVALANCHE PHOTODIODES AT LOW TEMPERATURES  .................. 63
   T. Yasumune, T. Maida, K. Maehata, K. Ishibashi and T. Umeno

X-RAY COMPUTED TOMOGRAPHY IMAGING METHOD WHICH IS IMMUNE TO BEAM HARDENING EFFECT  ............................................................... 73
   I. Kanno, A. Uesaka, S. Nomiyoa and H. Onabe

ESTIMATION OF IODINE THICKNESS WITH CsI(Tl) SCINTILLATOR CURRENT MODE DETECTOR  81
   K. Mikami, A. Uesaka, I. Kanno, M. Hashimoto,
   M. Ohtaka, K. Ara, S. Nomiyoa and H. Onabe

COMPOUND SEMICONDUCTOR InSb CRYSTAL GROWTH AND ITS ESTIMATION FOR THE SUBSTRATE OF RADIATION DETECTORS  ................................ 86
   N. Kamikawa, Y. Morita and I. Kanno
ON-LINE EVALUATION OF SPATIAL DOSE-DISTRIBUTION BY USING A 15m-LONG PLASTIC SCINTILLATION-FIBER

*A. Nohtomi, N. Sugiura, T. Itoh and S. Imamichi
Atomic Energy Research Institute, Kinki University
Kowakae 3-4-1, Higashi-Osaka-shi, Osaka, 577-8502, Japan

T. Torii
Environmental Monitoring Section, Japan Atomic Energy Agency
Shiraki 2-1, Tsuruga-shi, Fukui, 919-1279, Japan

H. Noma
A-Atom Technol Kindai Ltd.
Kowakae 3-4-1, Higashi-Osaka-shi, Osaka, 577-0818, Japan

1. INTRODUCTION

The long position-sensitive detector using a plastic-scintillation fiber (PSF) is an attractive device for the distributed radiation-sensing. Because the position determination is based on a simple principle, the application is generally easy to construct and moreover reliable. From this view, some developmental studies have been carried out in the past. Soramoto et al. used a 2.52 m PSF for the detection of neutrons from the fast neutron source reactor "YAYOI" in University of Tokyo(1). They also verified that it was possible to apply this method to a radiation sensing for the longer distance with connection of normal optical fibers and the PSF. Emoto et al. applied a similar system to the measurement of spatial dose distribution at a radiation field in a nuclear facility(2). The obtained count-rate distribution along a 5 m PSF was nearly identical to that of gamma dose-rate measured by a survey meter at several points.

The use of long PSF detectors is practically limited by the significant reduction of pulse height during the propagation of light signals inside the scintillation fiber, which is accompanied with the notable degradation of position resolution as well as counting losses. In the present work, a 15 m-long plastic-scintillation fiber has applied to the on-line evaluation of spatial dose

* Corresponding author; (tel)06-6730-5880, (fax)06-6721-3743, (e-mail)nohtomi@kindai.ac.jp
distribution in a neutron-gamma mixed field.

2. EXPERIMENTAL

Determination of radiation-incident position is achieved by the measurement of time difference that two directional signals of the scintillation light reach both ends of the PSF [so called "time-of-flight (TOF) method"]. The electronic schematic is drawn in Fig. 1. The electronic signals from the fast PMTs, after passing through two corresponding PM amplifiers and constant-fraction discriminators (CFD), are sent to the start channel of the time-to-amplitude converter (TAC) or to the stop channel of that with a proper delay time. The output pulse height is proportional to the time difference between the start input and the stop input, which is recorded by a PC-based multi-channel analyzer (MCA). Ten 15m-PSFs were bundled in order to enhance the detection efficiency of radiations.

Fig. 1  Schematic drawing of data acquisition system for the PSF system.

![Fig. 1](image-url)

Fig. 2 Position (TAC output) spectra for $^{137}\text{Cs}$ gamma-rays. The dimension of effective source region of $^{137}\text{Cs}$ is less than 5 mm. The source was placed on the surface of the PSF and no collimation was made. Figure 3 is the linearity between source position and peak channel obtained by the same measurement of Fig. 2.

<table>
<thead>
<tr>
<th>Counts / 500 sec</th>
<th>Position (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.5 m</td>
</tr>
<tr>
<td>20</td>
<td>3 m</td>
</tr>
<tr>
<td>40</td>
<td>5 m</td>
</tr>
<tr>
<td>60</td>
<td>7 m</td>
</tr>
<tr>
<td>80</td>
<td>9 m</td>
</tr>
<tr>
<td>100</td>
<td>11 m</td>
</tr>
<tr>
<td>120</td>
<td>13 m</td>
</tr>
<tr>
<td>140</td>
<td>15 m</td>
</tr>
</tbody>
</table>

Fig. 3 Linearity between source position and peak channel for $^{137}\text{Cs}$ gamma-rays.
The basic characteristics of position sensing were examined by using RI checking sources, a $^{252}$Cf source (spontaneous-fission neutrons, ~3.7 MBq) and a $^{137}$Cs source (662 keV gamma-rays, ~0.7 MBq). We evaluated the position resolution and the linearity between source position and peak channel. Pulse-height distributions of the PMT output were also measured for different source positions. Some long-time (2 ~ 3 days) measurements were done for the check of detection uniformity and stability by using only background radiations with no particular checking sources.

A performance test was carried out in the room of a research nuclear reactor "UTR-KINKI" at Kinki University. Count-rate distributions obtained at the neutron-gamma mixed field were compared with the direct readings of two survey meters (an air ionization-chamber and a neutron rem-counter) at several points.

### 3. RESULTS AND DISCUSSIONS

Position (TAC output) spectra for $^{137}$Cs gamma-rays is shown in Fig. 2. The dimension of effective source region of $^{137}$Cs is less than 5 mm. The source was placed on the surface of the PSF and no collimation was made. Figure 3 is the linearity between source position and peak channel obtained by the same measurement of Fig. 2.

![Fig. 2 Position (TAC output) spectra for $^{137}$Cs gamma-rays.](image)
From Fig. 2, the position resolution is estimated to be about 60 cm (at the center part of PSF) and about 75 cm (near the both edges of PSF) in FWHM. Throughout the whole length of 15 m, a good linearity is maintained between source position and peak channel as clearly shown in Fig. 3. Almost comparable results were obtained for $^{252}$Cf neutrons as shown in Fig. 4.
The position resolution estimated above is compared with the previously-reported values in Fig. 5. In the figure, the best resolution of each PSF, which was commonly obtained by the center part irradiation, is plotted as a function of the PSF length. As shown in the figure, the FWHM becomes larger with the increase of PSF length, indicating almost linear dependence. It is obvious that the degradation is originated from the significant reduction of pulse height during the propagation of light signals inside the scintillation fiber. The position resolution of the present application is effectively limited by the pulse timing properties of photomultiplier tube (PMT) used, especially "transit time spread". In addition to the inherent timing properties of PMT, the relative spread in transit times should vary intensively with the square root of the number of photoelectrons generated per pulse at the photocathode of PMT.

Fig. 5  Position resolution for different length PSFs.
Pulse height spectra of one-side PMT output signals were measured for different irradiation positions of $^{252}$Cf neutrons. As shown in Fig. 6, a steep reduction of pulse height was observed when the source was moved from 0.2 m to 15 m; the integral counts of each spectra decreased to $\sim 1/100$.

In order to examine the detection uniformity along the PSF, background radiations were utilized. Two ~ three days data accumulation was repeated several times for different settings. The results are shown in Fig. 7. Apparent inclination was noticed when the discrimination levels of both CFDs were equivalent (200 mV). After the start-side discrimination level was adjusted to 150 mV, rather reasonable uniformity was achieved. Some unremovable complicated-structures on the spectra, e.g. 50 ~ 60 channel, may be due to inherent defects of bundled PSF.
A performance test was carried out in the room of a research nuclear reactor "UTR-KINKI" at Kinki University, the maximum thermal output is 1 W. The PSF detector was arranged around the reactor core as photographed in Fig. 8. Count-rate distribution measurements were performed for 0.2 mW, 0.1 W and 1 W reactor operations. Each measurement time was chosen to be 600 sec except for the background measurement (about 1 night). As shown in Fig. 9, the count rate was almost proportional to the reactor power. Moreover, the relative count-rate distributions along the PSF were approximately identical to that of total dose rates measured by the survey meters at several point. This means the newly-developed detector system is available for quick check of the dose-distribution change during the reactor operation instead of conventional survey meters, such as air ionization-chambers or neutron rem-counters. It should be kept in mind that the PSF responses to neutrons and gamma-rays are essentially different and, therefore, the evaluation of dose-rate distribution at unknown neutron-gamma mixed fields is impossible only from the count rate information.
A 15m-long plastic scintillation fiber (PSF) detector has been applied to the on-line evaluation of spatial dose-distribution inside the room of a low power research-reactor. It was found that the present PSF detector has enough performance as the real-time measurement system which is not only quick and simple but also reliable for monitoring use in that situation. Such application may be also useful at the medical fields which routinely use radio isotopes for diagnosis purposes (such as PET facility). From the present observation, it seems that the practically-acceptable maximum limit of PSF length is at most 15 m. More than this, the severe signal reduction brings unavoidable difficulties for the following signal processing.

ACKNOWLEDGEMENT

The authors wish to thank Monju Development Department of JAEA for the kind supply of PSFs. This work was partly supported by cooperation with Chiyoda Technol Corporation.

REFERENCES

(4) Kinki University, Atomic Energy Research Institute   http://kuaeri.ned.kindai.ac.jp/
5. SUMMARY

A 15m-long plastic scintillation fiber (PSF) detector has been applied to the on-line evaluation of spatial dose-distribution inside the room of a low power research-reactor. It was found that the present PSF detector has enough performance as the real-time measurement system which is not only quick and simple but also reliable for monitoring use in that situation. Such application may be also useful at the medical fields which routinely use radio isotopes for diagnosis purposes (such as PET facility). From the present observation, it seems that the practically-acceptable maximum limit of PSF length is at most 15 m. More than this, the severe signal reduction brings unavoidable difficulties for the following signal processing.

ACKNOWLEDGEMENT

The authors wish to thank Monju Development Department of JAEA for the kind supply of PSFs. This work was partly supported by cooperation with Chiyoda Technol Corporation.

REFERENCES

(4) Kinki University, Atomic Energy Research Institute   http://kuaeri.ned.kindai.ac.jp/