The Development of a Mid-Dose Irradiator for Radiation Biology Study

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Summary

Recent we developed a mid-dose irradiator at KIRAMS using Cesium-137 sources for studies of mid-dose radiation effects in biology and also for a calibration of Thermo Luminescent dosimeter (TLD). In this paper, we will introduce the design, construction and performance test of the convenient mid-dose irradiator. The source housing of the irradiator contained three rods sources, which were separated by 10 cm in order to produce a uniform dose distribution. When operating to exposure the radiation to the biological samples, the source housing will rotate 180 degrees and face to biological samples, or TLD. After irradiating for the set time, it will return to its shielded position. A compact Field Point (CFP) controls the sequence of operation, interlock, motor rotation and safety system. The rotation speed of biological samples can vary up to 20 RPM. A real time monitoring system was also incorporated to check and control the operation status of the irradiator. The capacity of the irradiation chamber was 5 liters. The isodose distribution at arbitrary vertical plans was measured by using film dosimetry. The dose-rate was determined 1.25 cGy/min in air equivalent material in the case of 55.5GBq Cesium-137. The homogeneity of dose distribution in the chamber was within ±10%. The radiation level with a maximum 3 μSv/hr radiation leakage measured on its surface was considered within permissible levels for the operation.

Key words:
Irradiator, Cesium-137, Dose-rate, Mid-Dose

1. Introduction

There are so many studies using low and mid dose in the fields of biology and medical science. So, the men engaged in those fields demand the irradiator can dose the experimental material precisely. Also that irradiator needs to prevent radiation from leakage when the machine is under the operating because of using radio isotopes. Therefore the irradiator that is satisfied above mentioned demands is developed in this study.

There are several kinds of irradiators using radio isotopes. One is an irradiator for treatment of cancer patients and the others are for radiation effects research, experimentation and health side effects. One of the treatment machines using radio isotopes is a remote after loading system. An after loading system which transfers sources into cancerous tissue directly is also a part of primary radiation treatments. There has been a considerable increase in this form of cancer treatment because of accurate high dose-rates and low radiation side effects. Also, there are lots of irradiators for research to expose alpha, beta and gamma ray delivery from low dose to high dose[1-4]. A self-contained gamma ray irradiator has been developed for studies of mid dose radiation effects and also for calibration of TLD. It is a versatile gamma ray irradiator because source rods can be exchanged easily. It is particularly well suited for irradiating blood components, small animals, as well as other biological samples for radiation effects study. It is also possible to apply it in the field of agriculture for improving seeds by irradiation and for increasing shelf life in food. This irradiator can be also used as a standard radiation source for TLD calibration. This system has to be equipped with uniform dose distribution in the chamber and a large enough space for irradiating experimental animals easily and safely. The shielding and safety systems incorporated in the unit are designed to protect people from harmful amounts of radiation.

The design, construction and dose distribution in a convenient multi-purpose gamma irradiator that can change sources to Cesium-137, Iridium-192 and Cobalt-60 so on is described.

An irradiator stops functioning because it doses the experimental material using the radio isotopes that decay according as time goes. That time, the existing irradiators are done away. But the irradiator that is developed through

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this study can not only stock the source safely but also change the isotope source with source cassette.

2. Methods

The system configured with an input part, output part, control part and monitoring part. The input part was made up of several kinds of switches and a digital timer which controlled the irradiation time. The output part consisted of lamps to display the state of the irradiator, a motor to rotate samples and a cylinder to rotate the source 180 degrees. The control part controlled all parts and communicated to the computer for the operation states and emergency states. The CFP (Compact Field Point) controlled the sequence of operation, interlocks, motor rotation and safety systems. CFP could communicate with the computer using the TCP/IP method. The real time monitoring system was also implemented to check and control the operation status of the irradiator. The rotation speed of the biological sample varied up to 20 RPM in order to irradiate uniformly by changing the potentiometer on the control panel.

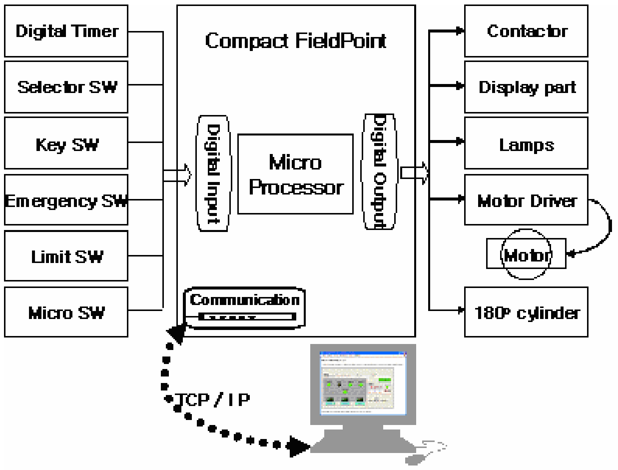

Fig. 1. System diagram

Sealed sources were made up of three rods that contained five Cesium-137 sources. Three rods which were 10 cm long were located equidistant with respect to the center of the chamber. The source housing also was curved to focus the irradiation to the center. Therefore, objects like biological samples could be uniformly exposed by sources without regard to position in the chamber.

Also, a shield block was constructed with 7cm of lead (Pb) to prevent radioactivity from sources escaping. Fig. 2 shows photograph of the chamber and schematic of the source housing. The change of source was very simple and convenient because the source rods could be separated and replaced easily. The radioactive sources were located in safe areas when the irradiator was not operating. Next, the whole source housing rotated 180 degrees and irradiated the samples with gamma radiation at the start of the process. The capacity of the irradiation chamber is 5 liters.

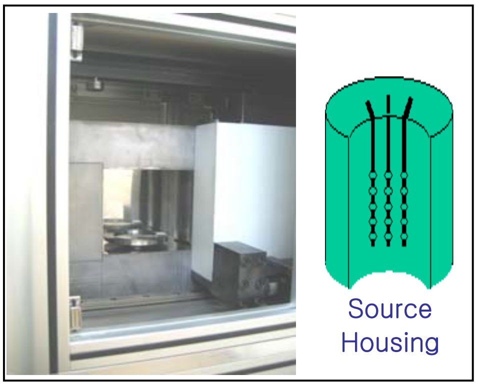

Fig. 2 Photograph of the chamber and Schematic of the source housing

The Control system is controlled by CFP. The CFP has digital I/O modules, analog I/O modules and TCP/IP module for communication with monitoring system. An operator or user can control the irradiator by pushing buttons, by setting the potentiometer for rotation speed of the samples and by setting the timer on the control panel. Fig. 3 shows a photograph of the irradiator. The adjustable speed of the canister is from 0 to 20 RPM. The irradiating dose can be controlled by a digital timer from a second to several hours. The rotary operation of the source by an electric-pneumatic system using an air pump prevents radiation leakage from the source because the radioactive source automatically returns to a safe area from an active area when accidents occur, like a shutdown of the main power supply or opening the door while operating.

Fig. 3 Photograph of the irradiator

The radioactive sources are useful for research and treatment of cancer, but they are very dangerous materials if exposed to the operator. Therefore, this system requires strong safety protocols. The monitoring program helps the operator to control the system in many ways. An operator can remotely control and view the status of the procedure during normal and emergency operation. If there is an error, the system informs the operator and provides a solution. Fig. 4 is main screen of the monitoring and control unit.

Fig. 4 Main monitoring screen

The irradiator system is operated not only by the manual control panel, but also remotely by using a mouse. The icons on the monitor are very similar to the control panel in the real irradiator system. In addition, the monitoring program tells the present system state and informs the operator about the next operation in the sequence with text messages and sounds. When an emergency state occurs, the system operates to prevent the radioactive source from being exposed automatically and simultaneously instructs the operator.

3. Results

The absolute dose-rate in the chamber was measured with a PTW No.192 0.6cc ion chamber and PTW Unidos 10005 electrometer which had already been calibrated with a Cobalt-60 source before measurement. This dose-rate was measured in air and also in water. The absolute dose-rate in air was measured at the center of effective space in the chamber for 1 minute. The absolute dose-rate in water was also measured. The dose-rate was determined 1.25cGy/min in air equivalent material in the case of 55.5GBq Cesium-137.

A gafcromic film 8.5 by 12.5 ㎠ was used for measuring the dose distribution at the center of the chamber. Because the position of the ion chamber which had been measured for absolute dose-rate was matched with the interval of film density, dose distribution according to position in the chamber could be calculated. The canister motor was rotated at 5 RPM for 60 minutes to irradiate material 75cGy in air at the same position to produce the same absolute dose-rate. A film densitometer read the density at 1 cm intervals in the chamber 8 by 8 ㎠.

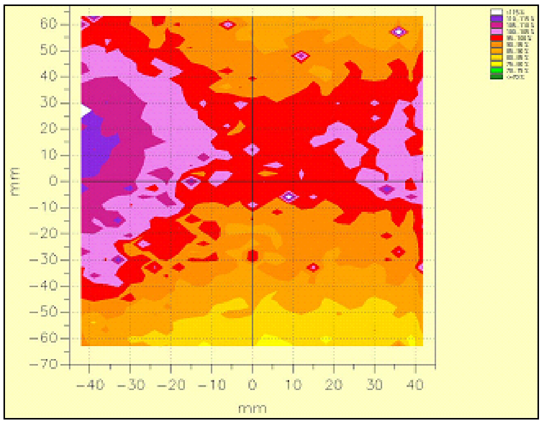

Fig. 5 Dose distribution

Fig. 5 shows the dose distribution at 1mm intervals after processing with the method of two dimension interpolation. The measuring unit is cGy in the figure.

The Dose distribution has a good homogeneity within ± 10 % error ratio, when compared to other irradiators.

Also, The Radiation level with a maximum 3μSv/hr radiation leakage measured on its surface was considered within permissible levels for the operation.

4. Conclusions

This irradiator was very well suited to investigate the biological effects of mid dose radiation. The capacity of the irradiation chamber was 5 liters. The dose-rate was 1.25cGy/min in air. The homogeneity of dose distribution in the chamber was within ±10%. The actual radiation level on the surface was within permissible level. The CFP controls the sequence of operation, interlock, motor rotation and safety system. The rotation speed of biological samples could vary up to 20 RPM. The real time monitoring system was also incorporated to check and control the operation status of the irradiator. The irradiator has a maximum of 3μSv/hr radiation leakage on its surface.

We plan to use the irradiator with uniform gamma rays on biological cells, blood and experimental animals to study radiation effects for low and medium dose radiation. In addition, we can also use the irradiator for TLD calibration.

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