CO7-1 Feasible Evaluation of Neutron Capture Therapy for Hepatocellular Carcinoma using Selective Enhancement of Boron Accumulation in Tumour with Intra-arterial Administration of Boron-Entrapped Water-in-Oil-in-Water Emulsion

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INTRODUCTION: We would like to apply BNCT, to radioresistant conditions as locally advanced or local recurrence of breast cancer, hepatocellular carcinoma, metastatic liver tumour, or lung cancer. Most of hepatocellular carcinomas (HCC) are thought to be incurable, and limited surgical operation, chemotherapy, or radiation therapies are available for a prolonged survival. Iodized poppy-seed oil (IPSO) has a property of depositing itself selectively in the cells of HCC. Higashi et al prepared a long term inseparable, water-in-oil-water emulsion (WOW) for use in arterial injection therapy to treat patients with HCC. The WOW was prepared by membrane emulsification technique using a controlled pore glass. In this study, we developed boron compound entrapped WOW emulsion and evaluated its efficiency of selective boron delivery to cancer tissues. We also evaluate neutron flux dosimetry in frontal irradiation position of BNCT simulation for a HCC patient with CTscan images using JCDS at Japan Atomic Energy Research Institute, and disscuss about the protocol for clinical trial of BNCT to HCC.

EXPERIMENTS: The ^{10}BSH-entrapped WOW emulsion was prepared with the double emulsifying technique.

Neutron dosimetry for BNCT was performed to a neutron beam. The JAERI Computational Dosimetry System (JCDS), which can estimate distributions of radiation doses in a patient's head by simulating in patient with a 7 cm tumour in the left lobe of liver. The Neutron Beam Facility at JRR4 enables to carry out boron neutron capture therapy with epithermal LiF collimation was used to selectively irradiate the tumour while sparing the adjacent normal organs. order to support the treatment planning for epithermal neutron beam BNCT, was developed .

RESULTS: We performed the dosimetry with JCDS in the condition of BNCT using epithermal neutron beams(Figure 2). To decrease side effects to neighbor normal organs, the RBE dose to normal liver limited to 4.9 Gy-Eq, the RBE dose to left lung limited to 2.3 Gy-Eq, the RBE dose to right lung limited to 2.9 Gy-Eq, and the max skin RBE dose limited to 3.2 Gy-Eq, according to the experience of BNCT for HCC by Suzuki et al. The minimum tumour RBE dose is 7.3 Gy-Eq, the mean tumour RBE dose is 21.8 Gy-Eq, and the maximum tumour RBE dose is 43.1 Gy-Eq. For calibration of the beam peaks to tumour, it is necessary to perform the operative BNCT irradiation with addition of some void to the spread the neutron beams to tumours.

With ^{10}B entrapped in WOW emulsion it is possible to deliver and retain boron atoms in cancer cells in tumor tissues through a catheter inserted in liver artery. These results show that ^{10}B entrapped WOW emulsions are most useful for arterial boron delivery for BNCT of cancer. We are now ongoing to plan clinical trials of BNCT for HCC patients, and hope to perform the first BNCT trial with WOW emulsions in the near future.

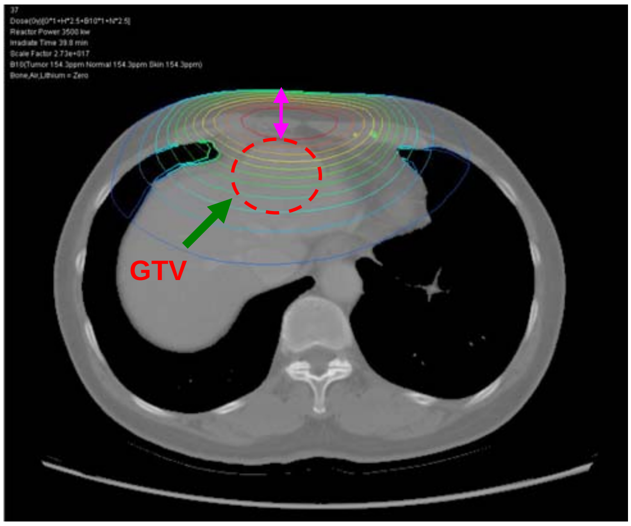

Figure 1. Neutron Dosimetry using JCDS for HCC patient in the situation of intra-arterial injection of ^{10}BSH-WOW.

REFERRENCE :

[1] H Yanagie, et al, Proceedings of IASTED Bioengineering 2010 (Innsbruck, AUSTRIA 2010) pp126-130, 201

採択課題番号 21034 中性子捕捉療法の一般外科領域癌への展開に向けた基礎的・臨床的研究 共同通常

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CO7-2 Performance Test of a Neutron Detector Using Side-Lighting Optical Fiber

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INTRODUCTION: To detect two-dimensional distribution of thermal neutrons is necessary for treatment of Boron Neutron Capture Therapy (BNCT). In general, two-dimensional array wavelength shifter fiber coupled with scintillator has been used as neutron imaging detector[1]. However, at the neutron field of BNCT, thermal neutron flux is very high up to 10^9 (n/cm^2/s)[2] compared with other neutron fields such as neutron scattering experiments etc.. The deterioration of the signal caused by radiation damage in wavelength shifting fiber will be serious problem to obtain precise information of thermal neutron image. To solve this problem, we have been developing a neutron detector using side-lighting quartz optical fiber. We report the performance test of our detector system to confirm the principle of side-lighting using the neutron field of the electron linear accelerator facility at KURRI.

EXPERIMENTS: Fig.1 shows schematic layout of side-lightning optical fiber coupled with plastic scintillator with ^{6}LiF for neutron detection. In general, optical fiber can take in the light through the edge of the fiber. In this research, optical fiber was specially fabricated with some bumps that work as lighting window. Plastic scintillators are located at the surface of bumps. Because bumps take in the light of experiment room, fibers coupled with plastic scintillator were surrounded by light shielding.

Gamma rays and charged particles generated from the reaction between ^{6}Li and thermal neutrons enter into scintillator. Scintillation lights enter into optical fiber via bumps and are transported to a photomultiplier. Output signals from a photomultiplier are converted to digital signal and stored by PC as light output distribution.

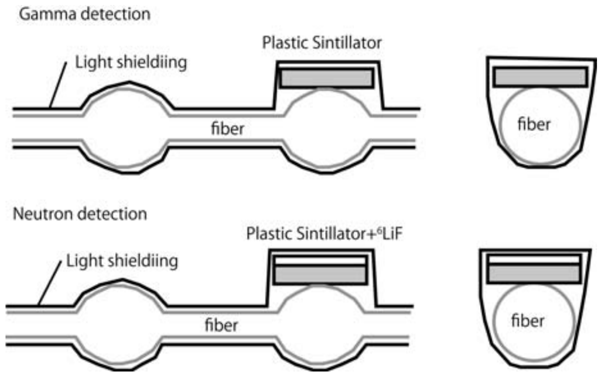

Fig. 1. Schematic layout of side-lightning optical fiber surrounded by light shielding.

The experiments were performed at the electron linear accelerator facility at KURRI. The electron beams with the energy of 30 MeV enter into Ta target. Photo-neutrons were generated from Ta(γ,n) reaction. These neutrons were moderated by light water surrounded by Ta target. Thermal neutrons and gamma rays were transported though 12 m flight tube and collimated with the size of 10 mm in diameter. This system was set behind the collimator.

RESULTS: Fig.2 shows the comparison of light output of plastic scintillator with and without ^{6}LiF neutron convertor, respectively. The events of gamma rays and neutrons are clearly shown in Fig. 2. It is realized that the side-lightning is successfully worked. Moreover, the events of neutrons were larger than that of gamma rays. It seems that events of neutrons can be discriminated by the subtraction of events of gamma rays obtained from plastic scintillator without ^{6}LiF. In this experiment, scintillators were set with the air gap. To improve light output, optical cement should be used between plastic scintillator and bumps of fibers.

In the future work, optical fibers with some bumps were cross arranged in rows to obtain two-dimensional neutron imaging.

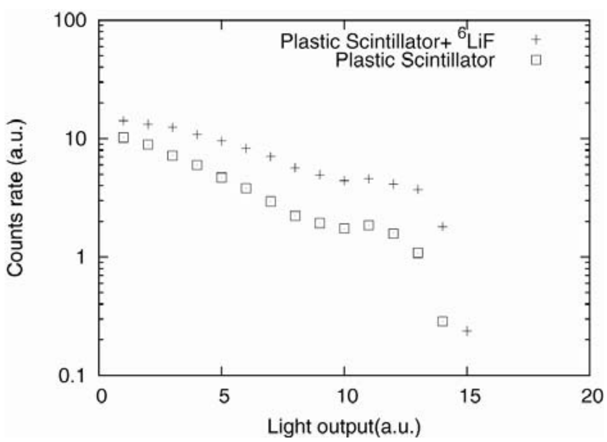

Fig. 2. Relationship between light output from plastic scintillator and counts rate irradiated with the neutrons and gamma rays.

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採択課題番号 21040　　横採光型光ファイバーを用いた中性子検出器の特性試験　　　共同通常
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CO7-3 Characteristic Estimation for D_2O Facility of KUR with Low-Enriched Uraniun Fuel

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INTRODUCTION: In the Heavy Water Neutron Irradiation Facility (D_2O Facility), the neutron beams with several energy spectra are available using the neutron energy spectrum shifter and cadmium filters [1]. In this facility, the researches for the wider fields, such as medicine, biology, engineering, pharmacy, *etc.*, have been performed. Especially as a medical use, boron neutron capture therapy (BNCT) has been performed, and the number of the clinical irradiation reached to 275 just before the KUR-operation stop in February 2006.
After the KUR-operation restart, the irradiation characteristics of the D_2O Facility may be changed due to the conversion to low-enriched uranium fuel. The accurate estimation and verification of the irradiation characteristics for the medical uses are important from the viewpoint of the quality assurance and quality control (QA/QC). In this study, the irradiation characteristics of this facility after the fuel conversion were estimated.
Unfortunately, the KUR-operation could not be restarted in 2009. Only the sensitivity calibrations of thermo-luminescent dosimeter (TLD) and multi-ionization chamber system for gamma ray, which are used in this study, were performed using the ^{60}Co Gamma-ray Irradiation Facility (Co-60 Facility).
MATERIALS: The material of the used TLD is beryllium oxide (BeO). The commercially-available BeO-TLD is capsulated in borosilicate glass, and it is very sensible for thermal neutrons. Then, the TLD capsulated in quartz glass is used in the D_2O facility.
For the multi-ionization chamber system, tissue equivalent (TE) chamber for neutrons and graphite chamber for gamma rays are selected. Both chambers are produced by Far West Technology, Inc. and those chamber volumes are 0.1 cc. For the electrometer system, "RAMTEC704" produced by Toyo Medic Co., Ltd. is used.
METHODS: The TLDs and ionization chambers were placed at the two selected point in the irradiation room of Co-60 Facility, in order to change the dose rate. The one point was 250-cm distant from the Co-60 gamma-ray source, and the other was 400-cm distant from the source. The nominal dose rates at the respective points were corrected by the comparison with the TLD-measured values. Then, the sensitivities of the respective chambers were calibrated on the basis of the corrected nominal values.
RESULTS: The TLD-measured values at the 250-cm and 400-cm-distant points were, almost 5-percent and 10-percent larger than the nominal values, respectively. This reason is thought to be that the influence of the scattered component from the irradiation-room wall was larger according that the measured point was more distant from the gamma-ray source. The correction factors to the nominal values were decided to be 1.05 and 1.10 for 250-cm and 400-cm-distant points, respectively.
Figures 1 and 2 show the time courses of the accumulated electric-charge for the multi-chamber system, at the 250-cm and 400-cm-distant points, respectively. It is found that the charge for the TE-chamber is smaller than that for the graphite chamber at the same point, namely at the same dose. The former charge is almost 70-percent for the latter one. When the ionization gas of the both chambers is change to air, the charge for the TE-wall chamber is 95-percent for that for the graphite-wall chamber, so the difference becomes smaller. This means that the response differences between the kinds of ionization chamber is more influenced by the kinds of ionization gas than by the kinds of chamber wall.
The response characteristic parameters, "dose/charge", were calculated using the corrected nominal values for the respective chambers. The values were obtained to 2.4 $\times 10^{11}$ Gy/C for the TE-chamber, and 1.7$\times 10^{11}$ Gy/C for the graphite chamber.

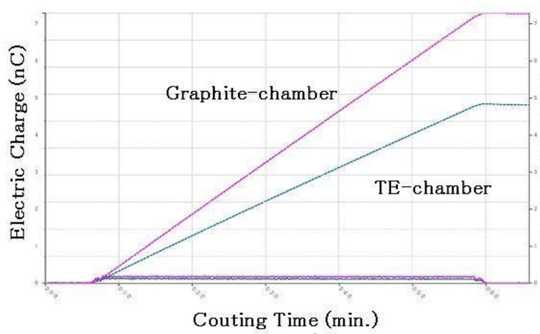

Fig. 1. Measurement results for the ionization chambers at the 250-cm-distant position.

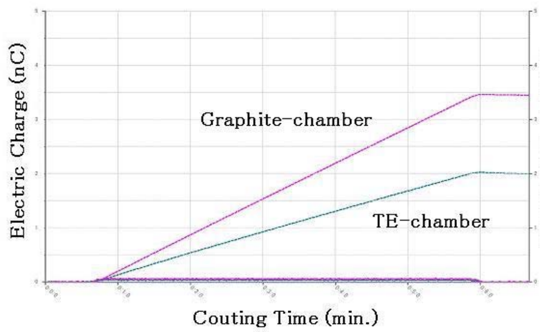

Fig. 2. Measurement results for the ionization chambers at the 400-cm-distant position.

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[1] Y. Sakurai *et al.*, Nucl. Instr. Meth. A **453** (2000) 569-596.

採択課題番号 21042　KUR 燃料低濃縮化後の重水中性子照射設備の特性評価　共同通常
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