STUDY ON ELECTRON MICROBEAM GENERATION FOR MRT BASED ON PHOTO-CATHODE RF-GUN*

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Abstract

We have been developing an MRT (Microbeam Radiation Therapy) based on Cs-Te photo-cathode RF-Gun at Waseda University. MRT is proposed to treat tumors by using array of several micro-meter parallel beams. In this therapy, irradiated normal tissue repairs itself, by contrast, even a non-irradiated tumor tissue dies. In the other words, the microbeam enhances the radiation sensitivity difference between normal and tumor issues. Therefore, MRT is considered one of the most useful tumor therapies in the future. We have generated electron microbeam by tungsten collimator slit and analyzed their dose distribution in air and in the PMMA phantom. We have used radiochromic film called GAFCHROMIC dosimetry film type HD-810 to measure them. We have compared these experimental results with Monte Carlo simulation of the dose distribution using the EGS5 code. In this conference, we would like to report the electron microbeam procedure, optimization of irradiation condition and evaluation of microbeam specifications.

INTRODUCTION

MRT (Microbeam Radiation Therapy) is a method to treat tumors using array of several micro-meter parallel beams (beam width of 20-50μm, center-to-center distance of 200-500μm). In this therapy, irradiated normal tissue repairs itself, by contrast, even a non-irradiated tumor tissue dies. In the other words, the microbeam enhances the radiation sensitivity difference between normal and tumor tissue. The schematic design of MRT is shown in Fig.1.

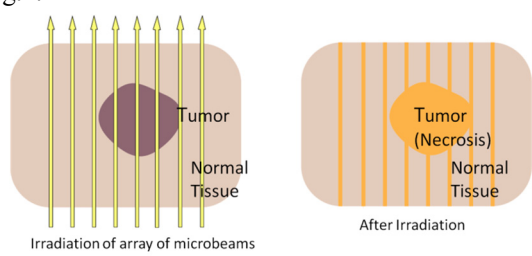

Figure 1: Schematic design of MRT.

Therefore, MRT is considered one of the most useful tumor therapies in the future. In order to achieve MRT, it is necessary to increase peak-to-valley dose ratio (PVDR) as high as possible. For that purpose, it is important to minimize the divergence of microbeam *in vivo*. In the previous study, PVDR must to be more than 10 for laboratory animal studies [1].Most of other MRT studies use x-ray source which can be generated only in large scale synchrotron facilities such as SPring-8 in Japan [1], the National Synchrotron Light Source at Brookhaven National Laboratory (NSLS) [2] and. at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France[3].Since these facilities are too large to install in hospitals, it is quite difficult from a practical perspective. Therefore, we have begun to develop electron microbeam for MRT based on Cs-Te photo-cathode RF-Gun which is very compact accelerator system (2.5m×3m size) at Waseda University. The merit of using electron microbeam is to get enough dose for MRT even in the small system. Since radiation burn hardly occurs because of specific effects of MRT, higher dose irradiation could be possible. Thus we will able to treat deeper tumor. Also, the MRT effect was reported experimentally but the mechanism was not completely confirmed. Such a small test facility would help the understandings of MRT effect. The purpose of this study is to optimize irradiation condition, and to evaluate microbeam specifications in order to start laboratory animal studies.

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EXPERIMENTAL SETUP

Photo-cathode RF-Gun and Laser System

The electron beam for MRT is generated from photo-cathode RF-Gun at Waseda University. The schematic design of RF-Gun system is shown in Fig.2. RF-Gun is composed of BNL type 1.6 cells cavity. The electron beam is emitted from Cs-Te cathode by the irradiation of UV laser light. The pulse repetition frequency of laser is synchronized with accelerating RF. UV laser is generated from IR laser by using two nonlinear optical crystals. The parameter of RF-Gun and laser system is listed in Table 1 [4].

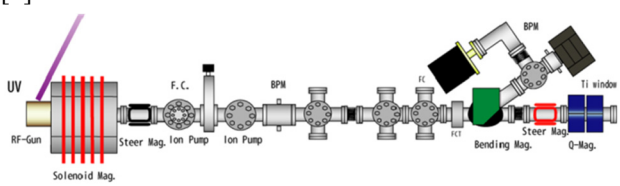

Figure 2: Schematic design of beamline.

Table 1: The Parameter of RF-Gun System

Wavelength of UV laser	262[nm]
Repetition Rate of RF	2856[MHz]
Current of the electron beam	~1[nC/bunch]
Maximum bunch number	100[bunches]
Maximum energy of the electron beam	~5[MeV]

The Dosimetry Method

To examine dose distribution, we used GAFCHROMIC HD-810 radiochromic film (ISP) [4] which changes into blue by irradiation. Optical Density (O.D.) of the irradiated film was measured with cooled CCD camera through a band pass filter. The film was placed on the white light illuminator in the dark box during measurement. For the dose calibration, we measured various O.D. films (*i.e.* various irradiation time). The dose rate was 28.6 Gy/sec at the Ti window. The calibration curve is shown in Fig.3, and we used it to converted O.D. into Gy.

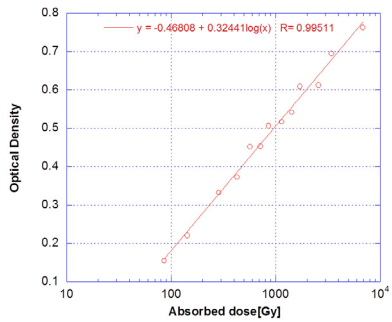

Figure 3: The calibration curve of HD-810 film.

The Collimator for Generation of Microbeam

Microbeam was generated from the 5mm thick tungsten single slit collimator. The collimator was fixed on the microstage to change the microbeam width. We measured microbeam width by using HD-810 films placed directly after the collimator, and then we compared them with the slit width. The result is shown in Fig.4. We have succeeded to generate microbeam with a width of 20-50μm.

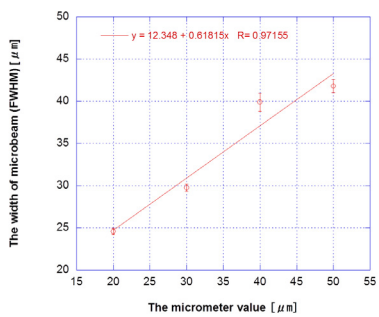

Figure 4: The slit width adjusted by the micrometer vs. microbeam width (FWHM) in the HD-810 film.

RESULTS AND DISCUSSION

Difference of the Divergence by using the Quadruple Magnet

In order to improve the transmittance of the beam, the beam was focused by using the quadruple magnet. Fig.5 shows the profile of the focused beam observed by the YAG screen.

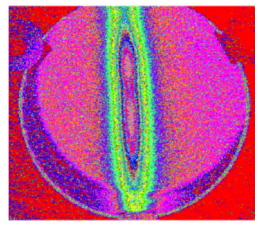

Figure 5: The profile of focused beam.

Moreover, we examined difference of the divergence by using the HD-810 film which was placed at an angle slightly shifted from the beam direction. The Schematic design of the experimental setup is shown in Fig.6. Thus we have obtained two-dimensional dose distribution using only one film. Fig.7 shows the divergence of non-focused beam and focused beam confirmed by using the film. The result shows that the divergence of focused beam is less than that of non-focused beam. This reason is that the divergence of solenoid magnet was offset by focus by the quadruple magnet. For this reason, we used focused beam for microbeam generation in this study.

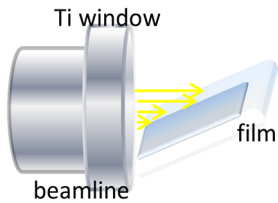

Figure 6: The schematic design of measuring the dose distribution using the HD-810 film.

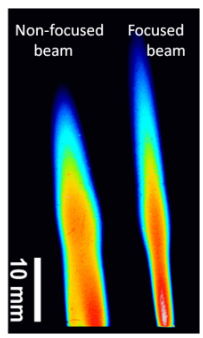

Figure 7: The divergence of non-foucued beam and focused beam measured by the film.

Multi-microbeam Irradiation

The method of multi-microbeam irradiation is irradiating next microbeam after moving films fixed on the motorized stage. The center-to-center distance of microbeam is depended on the distance of moving the stage. We measured the profile of multi-microbeam right after the collimator changing the beam width and center-to-center dis-

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tance of the beam. The profile and dose distribution is shown in Fig.8.

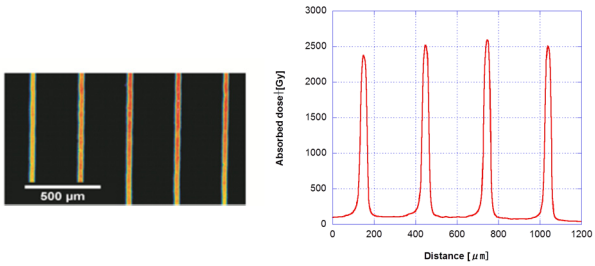

Figure 8: Left: The profile of multi-microbeam. Right: The spatial dose distribution (beam width:30μm, center-to-center distance:500μm).

We have succeeded to generate Multi-microbeam using the single slit collimator based on the photo-cathode RF-Gun at Waseda University.

PVDR Measurements in the Air and PMMA

We measured dose depth distribution at various beam width and center-to-center distance in the PMMA phantom using the HD-810 films. We set the films the same method to Fig.6. The profiles of films are shown in Fig.9.

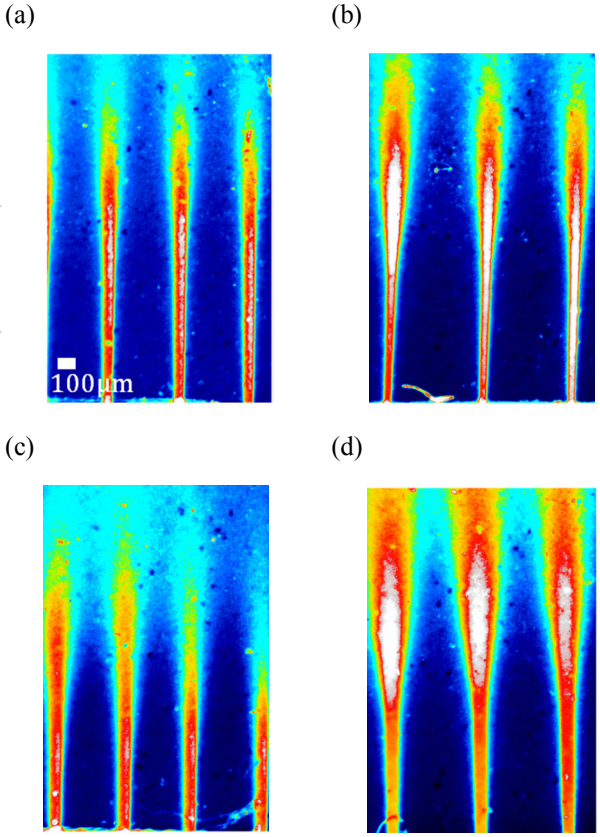

Figure 9: The microbeam distribution measured by films. (a) beam width: 20μm, distance: 400μm, (b) beam width: 20μm, distance: 500μm, (c) beam width: 30μm, distance: 400μm, (d) beam width: 30μm, distance: 500μm.

We measured PVDR changing beam width, center-to-center distance and depth. Furthermore, we calculated PVDR using the EGS5 Mote Carlo simulation code. The PVDRs at the depth of 0.5mm and 1mm are listed in the table 2.

Table 2: PVDRs at the Depth of 0.5mm and 1mm

Depth [mm]	Width and distance[μm]	PVDR (Measured)	PVDR (Simulated)
0.5	20-400	11.3	147.9
0.5	20-500	26.8	192.8
0.5	30-400	20.1	146.3
0.5	30-500	24.2	198.1
1.0	20-400	8.67	19.6
1.0	20-500	16.7	33.8
1.0	30-400	5.94	17.2
1.0	30-500	12.6	30.7

Setting to beam width of 20 to 30μm and center-to-center distance of 400-500μm, we have succeed to obtain enough PVDR for MRT within the depth of 1mm both of measured and simulated. In the low dose region such as valley, the accuracy of the dose measurement was not enough. . Therefore, the value of measured PVDR is less than that of calculated PVDR of EGS5 at the depth of 0.5mm. We conclude that the measurement results and EGS5 results have same behaviour depending on the depths, widths and distances.

CONCLUSIONS AND PROSPECTS

We have succeeded to generate electron microbeam for MRT based on the photo-cathode RF-Gun at Waseda University. Around the surface of animal skin, it is possible to start for laboratory animal studies by setting to beam width of 20 to 30μm and center-to-center distance of 400-500μm.

We are planning to start for laboratory animal studies using legs of mice.

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