Micron-scale Dose Profiling for Hard X-ray Microbeam Exposure

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1. Introduction

The Radiation Bioengineering Laboratory (RadBio Lab) at Seoul National University (SNU) has built a hard x-ray irradiation facility for radiation biology and radiation protection studies. In this study, we installed a micron-sized beam collimation and beam profiling system in the facility. As compared to the earlier microbeam systems employing mono-energetic charged particles or characteristic X-rays [1-4], our system utilizes bremsstrahlung X-ray beam carrying energy of up to 450 keV.

2. Materials & Methods

2.1 System specification

The hard x-ray irradiation facility consists of an x-ray beam tube (450-D08, YXLON, Germany), a high voltage power supply, a target cooler, a system control unit and shielding systems. The maximum operating anode voltage is 450 kV and the tube current is limited to 10 or 20 mA depending on the operating anode voltage. The solid angle of beam outlet is 40° and beam of energy below 20 keV is removed by a 3 mm-thick aluminum filter.

Beam is collimated in three stages. The first stage is made of a toroidal lead collimator, which guides the beam only downward in perpendicular to the beam cross section. Two sets of 30 mm-thick parallel lead blocks play the second stage collimator. Each set of lead blocks move in X and Y direction, respectively, controlled by separate servo motors (HC-KFS13B, MITSUBISHI, Japan). Passing through the second stage collimator, tetragonal beam comes out. Beam collimation is finalized with a pair of 2 mm-thick tungsten plates. The beam opening at the final stage is controlled by 100 μm per step.

The facility is equipped with a lab table, that has fixing pin holes, under the beam collimating system. The lab table is controlled by two separate servomotors (HC-KFS13B, MITSUBISHI, Japan) each for X- and Y-directional movement at 100 μm per step. Tissue equivalent phantom and experiment sample are placed on this lab table. The main table can be located manually in a varying distance from the beam exit. Fig. 1 is a schematic of the microbeam irradiation system in the RadBio Lab at SNU.

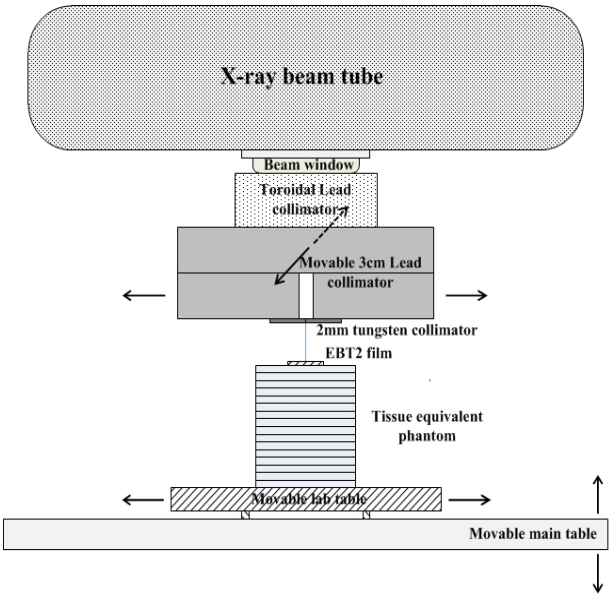

Fig. 1 A schematic of the microbeam irradiation system in the RadBio Lab at SNU.

2.2 Dosimetry scheme

Radiation dose delivered to experiment samples can be measured by film dosimetry using gafchromic EBT2 film (ISP, USA). Gafchromic EBT2 film changes its color in response to radiation exposure. The LINAC (CL2100C, Varian, USA) x-ray beam at SNU hospital was used to obtain a dose calibration curve for EBT2 film. [5] Dose is calculated from the optical density of EBT2 film, by running an image analysis program of our own based on MATLAB with image data obtained using a flatbed color laser scanner (Expression 10000XL, EPSON, Japan). The scanning resolution of the scanner is set at 1200 dpi (corresponding to 21 μm per pixel).

3. Results

3.1 Dose profiling

Beam collimation was made for 1 and 2 mm at FWHM by operating the second-stage lead collimator. Then, the microbeam of 150 μm at FWHM was set by controlling the third-stage tungsten collimator. Beam tube was operated at 150 kV anode voltage and 15 mA tube current. The tube current was set at the maximum allowed at 150 kV on account of the infinitesimal

opening of the tungsten collimator. EBT2 film was positioned on a tissue equivalent phantom at beam exposure. Fig. 2 shows dose profiles for hard x-ray beams of (a) 2 mm, (b) 1 mm and (c) 150 μm at FWHM. As the beam opening is narrowed down, the penumbra region is reduced and the number of scattered photons reaching out the penumbra also decreases.

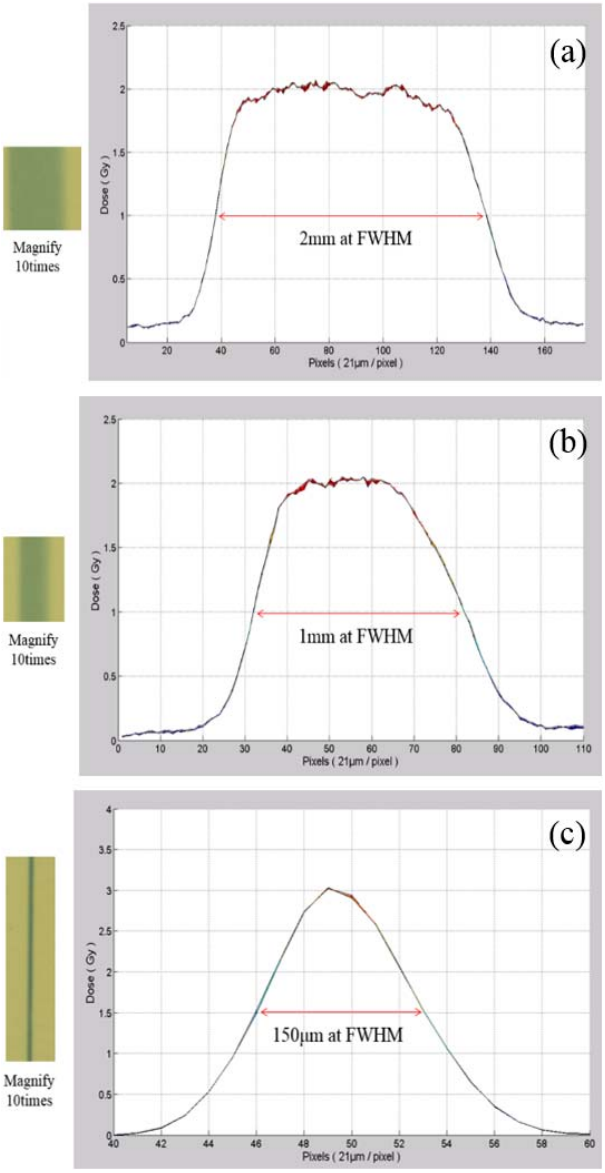

Fig. 2 Dose profiles for hard x-ray beams of (a) 2 mm, (b) 1 mm and (c) 150 μm at FWHM**.**

3.2 Precision of microbeam exposure

EBT2 film was exposed to the beam of 150 μm at FWHM at 9 mm intervals in X-direction by automatic movement of the lab table at 100 μm per step. The image of scanned film (Fig. 3(a)) was analyzed to produce 2-D (Fig. 3(b)) and 1-D (Fig. 3(c)) dose profiles. In Fig. 3(b), the peak dose varies along Y-direction of each slit with minimal difference of less than 10%.

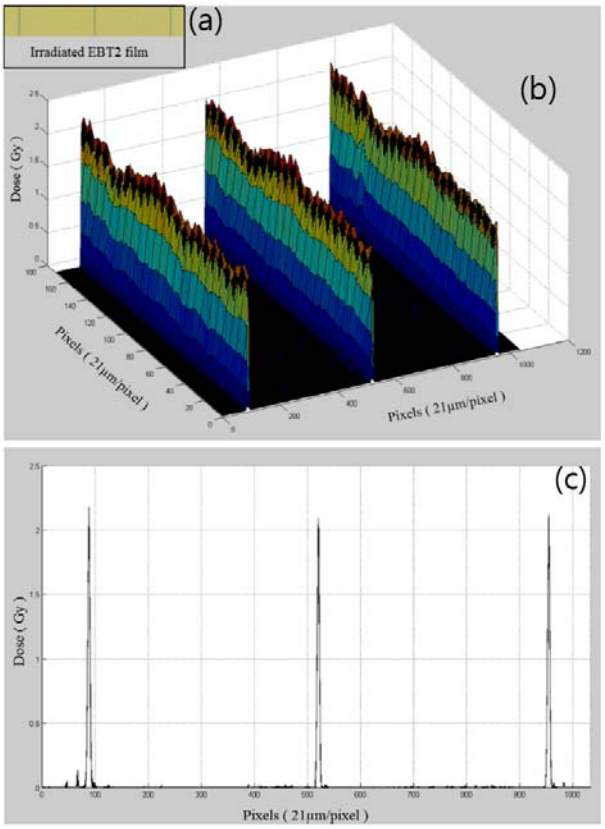

Fig. 3 Microbeam exposure by automatic control: (a) image of film optical density, (b) 2-D dose profile, and (c) 1-D dose profile.

4. Conclusion

Automatic control of beam opening in micron scale has been realized for a hard x-ray beam. The beam is accompanied with a penumbra of limited size. Dose profiling also has been performed in a micron scale precision. The automatic system for sequential delivery of microbeam has been observed to be precise in beam collimation and stable in beam intensity control.

REFERENCES

[1] L. A. Braby and W. D. Reece, Studying Low Dose Effects Using Single Particle Microbeam Irradiation. Radbiat. Prot. Dosim. 31, 311-324 (1990).
[2] G. Randers-Pehrson, C. R. Geard, G. Johnson, C. Elliston and D. Brenner, The Columbia University Single-Ion Microbeam. Radiat. Res. 156, 210-214 (2001).
[3] M. Folkard, G. Schettino, B. Vojnovic, S. Gilchrist, A. G. Michette, S. J. Pfauntsch, K. M. Prise and B. D. Michael, A Focused Ultrasoft X-ray Microbeam for Targeting Cells Individually with Submicrometer Accuracy. Radiat. Res. 156, 796-804 (2001).
[4] G. M. Sun, E. H. Kim, K. B. Song, J. W. Jeong and H. D. Choi, Preliminary results of the beam control and detection of the KIRAMS electron microbeam system, Nucl. Eng. Tech. 37, 185-190 (2005).
[5] K.M. Lee, S. R. Kim and E. H. Kim, Characterizaion of Dose Delivery in a Hard X-ray Irradiation Facility, J. Nucl. Sci. Technol. 49, 655-661 (2012).