Monte Carlo Simulation of Small Photon Beam Measurements by Beam Intensity Scanner System(BISS)

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ABSTRACT

We have developed and used BISS as a radiation detector to verify patient dose and determine the physical characteristics of beams used in Stereotatic Radio Surgery(SRS) and Intensity Modulated Radiation Therapy(IMRT). In order to confirm the function and accuracy of our BISS, we simulate our measurements by BISS under the radiation of 6MV photons from a Varian Clinac 21EX equipped with a 60 leaf pairs MLC. For the simulation based on the Monte Carlo algorithm, which remains the most comprehensive and accurate theoretical method to verify beam profiles, we use the BEAM code. Compared with the measurements by BISS, our simulation of variously shaped phantom measurements show good agreements. Our simulation results can be used as a theoretical standard to compare and confirm measurements by BISS and other dosimeters such as ultramicro cylindrical ionization chamber(UCIC) and radiographic film.

Keywords: radiation detector, DVCS, IMRT, Monte Carlo simulation, Dosimeter, BEAM code

1. INTRODUCTION

Patient dose verification is one of the most important parts in quality assurance of the treatment delivery for radiation therapy. Air-filled small volume ionization chamber, film dosimeter, silicon diode, thermoluminescence dosimeter and diamond detector are most often used for the measurement of relative dose distributions in radiotherapy. Each detector mentioned above has advantages and disadvantages in measurement characteristics. In SRS, small fields of 1.0×1.0 to 3.0×3.0cm^2 are used and it is desirable to make a detector showing more sensitive response to positions of absorbed dose in such a small field sizes. Motivated by this, we have developed and used BISS as a radiation detector[1] to verify patient dose and determine the physical characteristics of beams used in SRS and IMRT. Our BISS dosimeter is able to scan across the small beam profile down to 1.0×1.0cm^2 in rectangular and ϕ1.0cm dimension of circular shaped and accurately reproduce three dimensional relative dose distribution by means of the digitized fluoroscopic signals. As a method to confirm the function and accuracy of our BISS, we simulate our measurements by BISS under the radiation of 6MV photons from a Varian Clinac 21EX equipped with a 60 leaf pairs MLC. For the simulation based on the Monte Carlo algorithm, which remains the most comprehensive and accurate theoretical method to verify beam profiles, we use the BEAM code[2].

2. METHODS

Among the various measurements by BISS, the "Lion Teeth" shaped modulator has a unique shape and dimension like the Fig. 1. Due to its shape and dimension, we can easily determine whether some measurement or simulation is valid or not. Therefore, we compare the BISS measurement of Lion Teeth Modulator under the radiation of 6MV photons from a Varian Clinac 21EX equipped with a 60 leaf pairs MLC with Monte Carlo simulation. The simulation is performed using our Linux based four node cluster computing system composed of 2.2GHz Intel CPUs. The position, energy, angle and weight of scored particles were stored in a phase space file whose size is about 1~2GB. The stored phase space files were used repeatedly for analyzing beam or as input to the DOSXYZ code to calculate the dose distributions around the Lion Teeth modulator. In our simulation, AE=ECUT=0.70MeV, AP=PCUT=0.010MeV and

electron range rejection technique was used in order to reduce the simulation time.

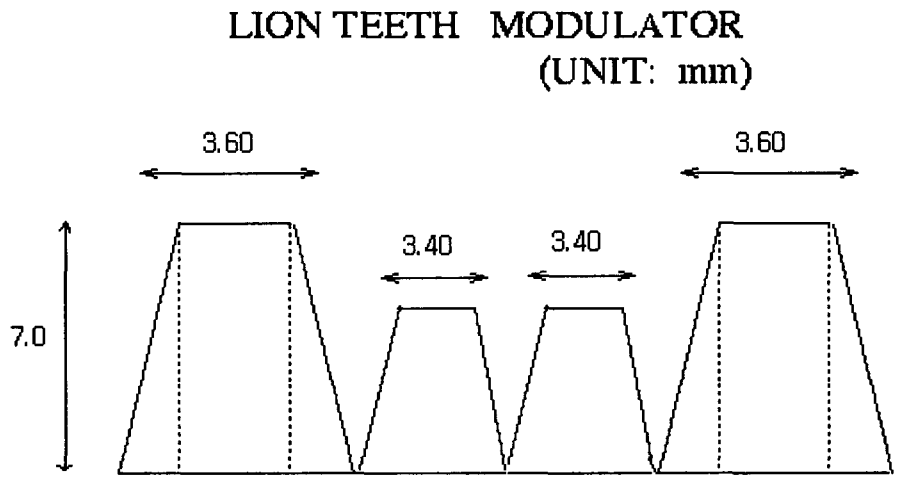

Fig. 1 Lion Teeth Modulator

3. RESULTS AND CONCLUSION

In our BISS measurements, the photon beam of 6MV was generated by a Varian Clinac 21EX linear accelerator. The Lion Teeth Modulator was positioned at SSD=100cm where the field size was $3\times3\,cm^2$ and the incoming dose rate was 300MU/min. In Fig. 2, our measurement is depicted.

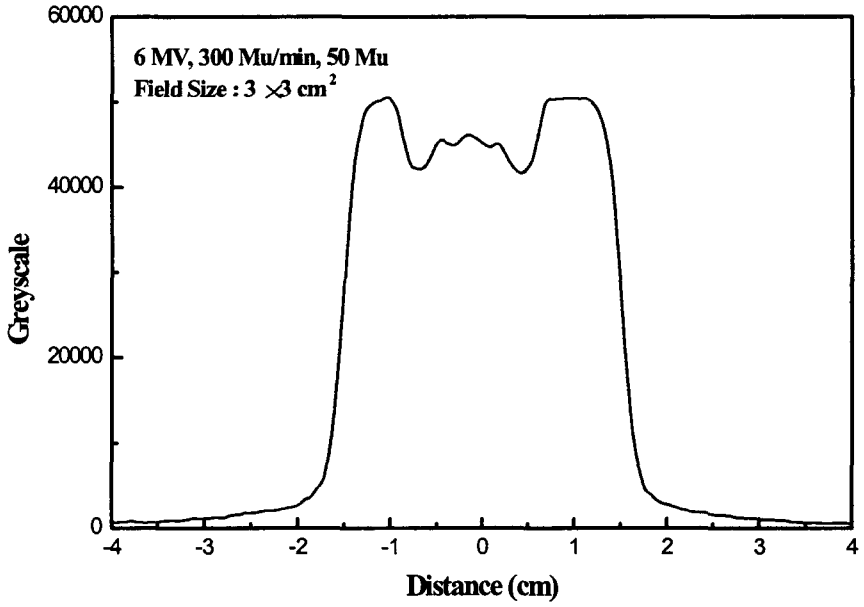

Fig. 2 BISS measurement of Lion Teeth Modulator

Our simulation result is depicted in Fig. 3. It shows the normalized beam energy in each voxel (with 0.05mm) after the beam passed through the Lion Teeth Modulator. It shows the characteristics expected for a Lion Teeth Modulator. At the position of the three valleys of the Lion Teeth Modulator, the beam intensity increase sharply in both the measurement and simulation. This result confirms that BISS is an accurate dosimeter that can verify the relative amount of delivered dose from the accelerator. There exists one noticeable difference between the measurement and simulation. The tail part of the measurement is longer and thicker than that of the simulation. This difference may due to the scattered electrons[3] and positrons. Right now we are trying to pin down the reason for this difference.

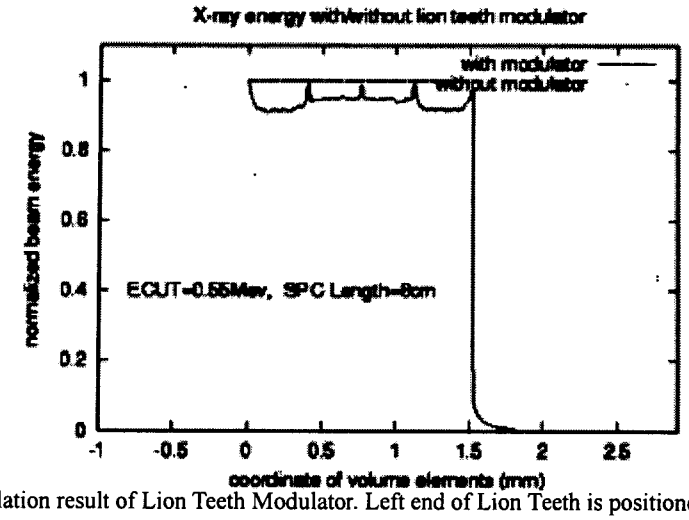

Fig. 3 Simulation result of Lion Teeth Modulator. Left end of Lion Teeth is positioned at the origin.

4. DISSCUSION

Considering its dosimetric characteristics confirmed by our Monte Carlo simulation, the study of the radiation dosimetric technique using BISS may provide an accurate pre-treatment verification tool for the small beam used in SRT and can be applied to the verification of three dimensional dose distribution in IMRT. Furthermore, our simulation results can be used as a theoretical standard to compare and confirm measurements by BISS and other dosimeters such as ultramicro cylindrical ionization chamber(UCIC)[4] and radiographic film. An in-depth study to compare simulation result with various measurements mentioned above is in progress.

5. ACKNOWLEDGMENT

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