IOP Conf. Series: Materials Science and Engineering **93** (2015) 012067 doi:10.1088/1757-899X/93/1/012067

Comparison of the calculated and experimental data of the extracted electron beam profile

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Abstract. The current commercial use of electron accelerators grows in research, industry, medical diagnosis and treatment. Due to this fact, the creation of a model describing the electron beam profile and shape is an actual task. The model of the TPU microtron extracted electron beam created in the program "Computer Laboratory (PCLab)" is described and compared with experimental results in this article. The value of the internal electron beam divergence determination is illustrated. The experimental data of the electron beam profiles at the selected distances from the output window are analysed and compared with the simulation data. The simulation data of the electron beam profiles are shown.

1. Introduction

Nowadays, the X-ray sources and the particle accelerators have a large number of practical applications, particularly medical applications, but they are also used for a variety of biological and industrial applications [1-4]. Particle accelerators have an amazingly broad range of beam parameters for different applications such as sterilization of food products, pulsed X-ray radiography, external beam radiotherapy and plasma heating for fusion reactors [1-5]. In all these applications it is necessary to have an accurate representation of the electron beam profile and shape and be able to predict the beam parameters in accordance with the particular use. Therefore the creation of a model describing the electron beam profile and shape is a contemporary task.

The majority of programs use for the simulation of electron beams the Monte Carlo method or the macro Monte Carlo method [6-8]. In this paper the simulation is carried out by applying the Monte Carlo method.

In the present research the theoretical analysis of the TPU microtron extracted electron beam was carried out. The model of the accelerator electron beam profile and shape was developed in the framework of the program "Computer Laboratory (PCLab)" and was compared with the experimental results. The following characteristics of the electron beams are analysed in this research: the internal beam divergence and the electron beam profile and shape.

2. Materials and methods

2.1. Emitting source

In this experiment, the TPU microtron extracted electron beam, with the following characteristics was used as the emitting source: beam size at output ≈ 2.0 mm^2; electron energy – 6.1 MeV.

2.2. Simulation program

For the model creation of the TPU microtron extracted electron beam, the program "Computer laboratory (PCLab)" version 9.6 was used. Simulation is carried out using the Monte Carlo method. The software package of "Computer laboratory (PCLab)" allows the calculation of the propagation process of photons, protons, electrons and positrons in matter with specified characteristics [9].

2.3. Experiment geometry

For the first measuring, the scan frame was placed at the distance equal to 10 cm from the output window and the horizontal and vertical profiles of the microtron extracted electron beam were measured. The scan frame was shifted by additional 5 cm away up to a distance 35 cm from the output window in each subsequent measurement. The Faraday cup was located at a distance of 60 cm from the output window.

In the simulation, the normal plane disc (diameter – 2.0 mm) monoenergetic electron source with energy of 6.1 MeV corresponding to the actual TPU microtron beam was used. The source was placed in front of the beryllium output window (diameter – 40 mm; thickness – 50 μm). The beam shape analysis was carried out in the air.

The figures 1, 2 show the experimental setup and the calculation geometry, correspondingly.

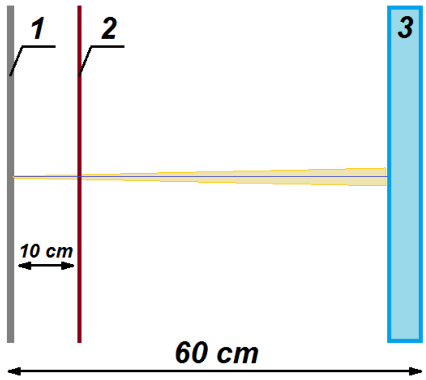

Figure 1. Scheme of the experiment: 1 – beryllium output window, 2 – scan frame, 3 – Faraday cup.

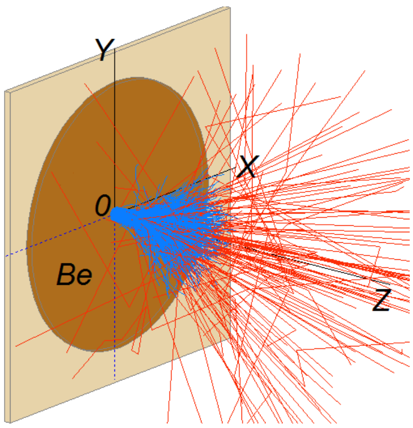

Figure 2. The calculation geometry: blue lines – electron path; red lines – photon path.

3. Results and discussions

The horizontal and vertical profiles of the microtron extracted electron beam were measured at specified distance from the microtron output window. Data from all measurements were analysed and fitted with the Gaussian function. The horizontal and vertical profiles were averaged and the half widths at half maximum were determined for those profiles.

The figure 3 shows an example of experimental data approximation with the Gaussian function for the horizontal profile of the microtron electron beam. The beam profile is normalized to the maximum value. The frame distance from the microtron output window is equal to 15 cm.

The angle of internal divergence of the microtron electron beam α was obtained by linear approximation of the half width at half maximum values – α = 2,5°.

The figure 4 shows the determination of the internal divergence angle of the microtron electron beam α by linear approximation, where R is the frame distance from the microtron output window and d is the half width at half maximum value.

Knowing the internal divergence of the beam, the beam model was developed, followed by comparing beam profiles obtained experimentally and beam profiles obtained by simulation.

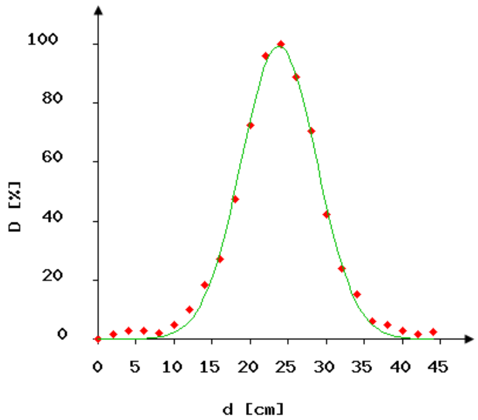

Figure 3. Horizontal profile of the microtron extracted electron beam: ◆ – experimental results; — – approximations result.

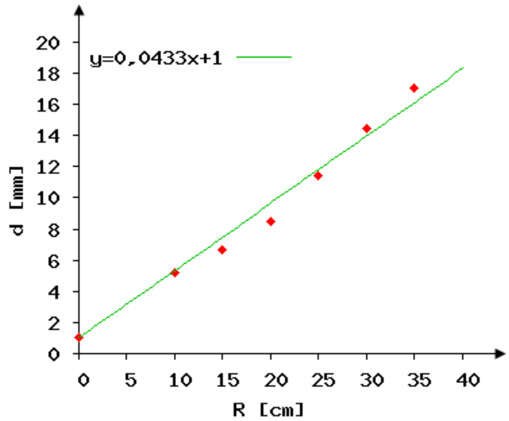

Figure 4. Determining the angle of internal divergence of the microtron electron beam.

In the figure 5 the comparison of electron beam profiles obtained experimentally and electron beam profiles obtained by simulation are shown for three different scan frame distances from microtron output window.

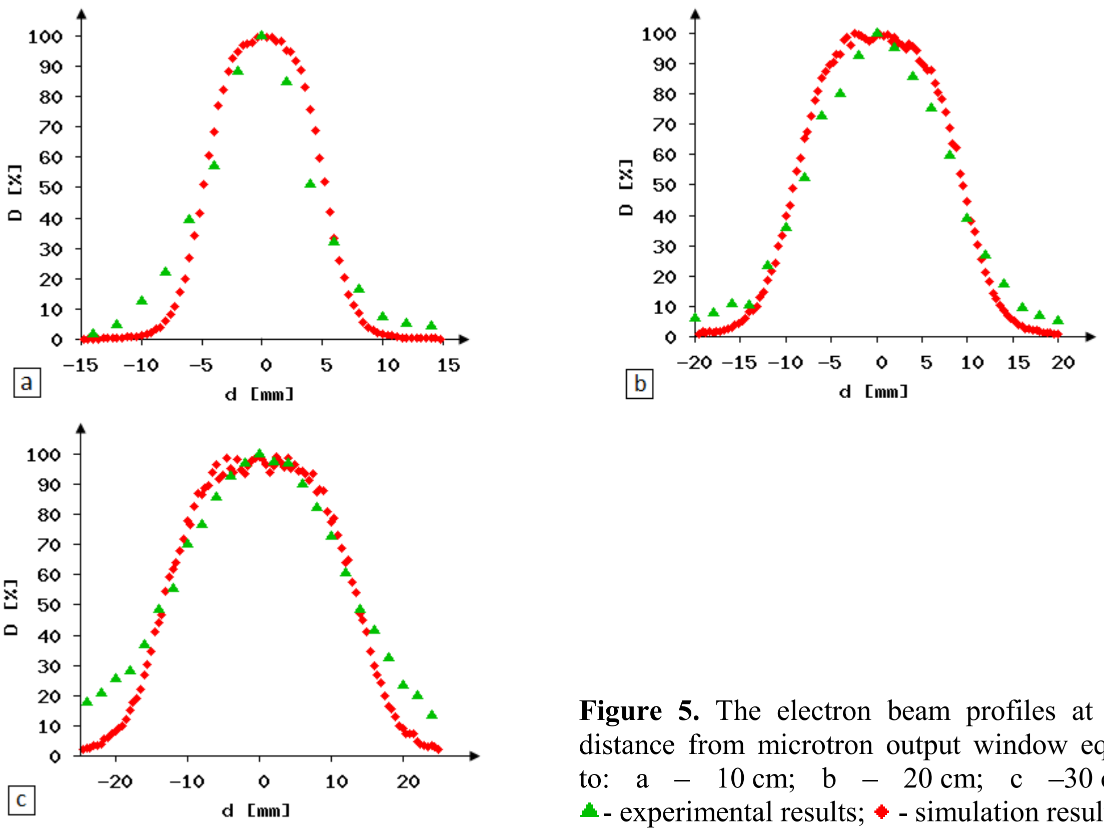

Figure 5. The electron beam profiles at the distance from microtron output window equal to: a – 10 cm; b – 20 cm; c –30 cm; ▲ - experimental results; ◆ - simulation results.

The figure 5 illustrates that results from the model are in a good agreement with the experiment.

The simulation data of the TPU microtron extracted electron beam profile at the 0 cm, 5 cm and 15 cm distance from the output window are shown in the figure 6. The dose results were averaged and normalized to the maximum simulation dose in the layer.

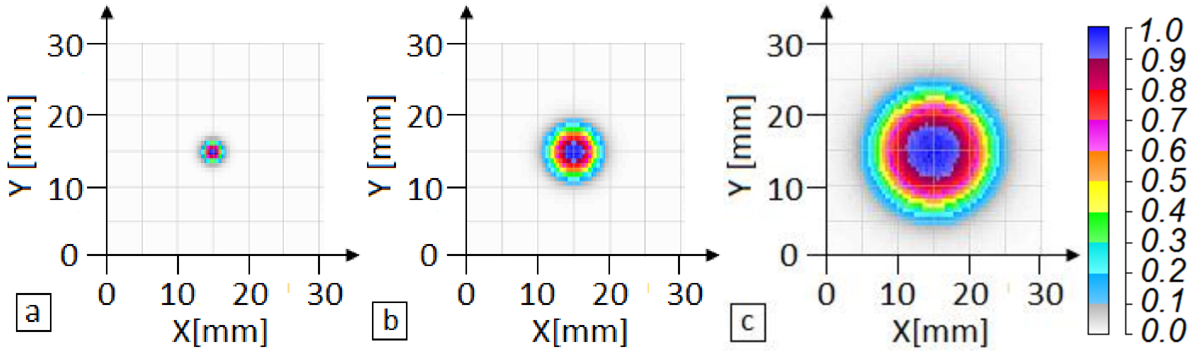

Figure 6. The TPU microtron extracted electron beam profile: a – at the 0 cm distance from the output window; b – at the 5 cm distance from the output window; c – at the 15 cm distance from the output window.

4. Summary

The theoretical model of the TPU microtron extracted electron beam was calculated in the simulation program "Computer laboratory (PCLab)" and compared with experimental data in this paper. The obtained results show the eligibility of this program for the real electron beams analysis and therefore the program can be used later, for example in the development of the accelerator's collimating system.

The theoretical model allows to estimate the dose distribution and the electron beam size at the selected distance from the output window, making it faster and easier to determine these characteristics than the actual measurements. The depth dose distribution allows computing the radiation burden values in the electron beam propagation direction.

Acknowledgements

This work was partly supported by Competitiveness Enhancement Program of Tomsk Polytechnic University.

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