HOMOGENEITY OF ELECTRON ACCELERATOR DOSE DISTRIBUTION

Ivana Klačková[1], Andrea Šagátová[1,2], Marko Fülöp[2], Vladimír Nečas[1]

[1]Institute of Nuclear and Physical Engineering, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovičova 3, 812 19 Bratislava, Slovakia,

[2]University Centre of Electron Accelerators, Slovak Medical University, Ku kyselke 497, 911 06 Trenčín, Slovakia

E-mail: ivana.klackova@gmail.com

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1. Introduction

Electron accelerators and radiation emitted from them is widely used in industry for radiation sterilization, modification of materials, environmental treatment etc [1,2,3]. Further in medicine for radiation treatment of oncological patients and also in research.The aim of this work was to study homogeneity of a dose distribution when using an industrial electron accelerator with scanning electron beam in one direction. We have studied broadening of an electron beam passing through the air in direction perpendicular to direction of beam scanning and distribution of a dose along a scanning electron beam. The main result of the experiment was to define the maximum width of a small object, which can be irradiated by electrons from accelerator in static mode, and the dose in the object will differ in 1 %, 2 % or 5 % at most.Moreover, we have determined how the maximum width increases with increasing distance from the accelerator exit window as the electron beam broadens in the air. Measurements were made for the linear accelerator UELR-5-1S in Trenčín and obtained results find practical application when deciding how to irradiate samples at this facility.

2. Experimental Details

Homogeneity of a dose distribution along a scanning electron beam and in direction perpendicular to direction of its scanning has been measured. Measurement was done at the linear electron accelerator UELR-5-1S [4] at University Centre of Electron Accelerators in Trenčín. Parameters of the UELR-5-1S accelerator during experiment are listed in Tab.1.

Tab. 1: UELR-5-1S accelerator parameters.

Beam power	190 W
Beam energy	5 MeV
Beam scanning width	40 cm
Beam scanning frequency	0.25 Hz
Beam repetition rate	40Hz
Beam initial diameter	11 mm

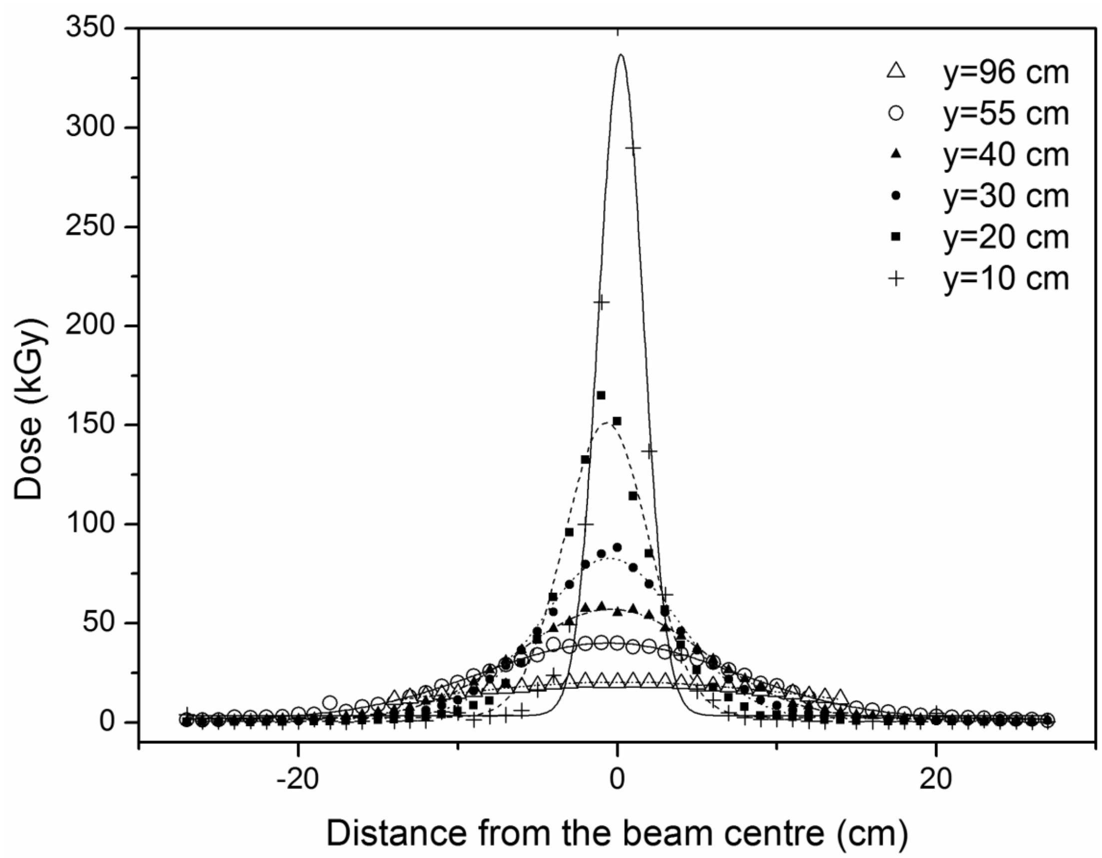

Fig.1: *Graph of measured dose depending on the position from the centre of the beam in direction perpendicular to beam scanning, at various distances from the accelerator exit window (labelled y).*

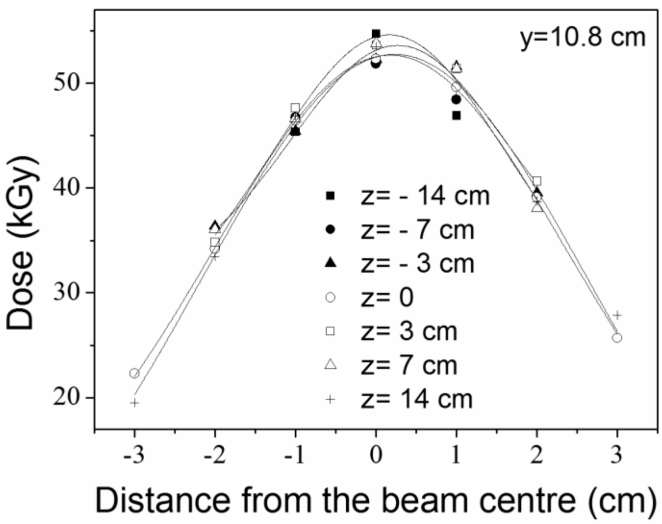

Fig.2: *Graph of the measured dose depending on the position from the centre of the beam in direction perpendicular to beam scanning, at various positions along the scanning distance marked from the centre of the accelerator window (labelled z).*

Dose distribution of the electron beam in direction perpendicular to direction of its scanning have been measured for various distances from the exit window of the accelerator namely for 96, 55, 40, 30, 20, 10 cm, with accelerator setting according to Tab. 1. Determination of a dose distribution in direction along the scanning electron beam have been done for longitudinal distances from the centre of the accelerator window i.e. -14, -7, -3, 0, 3, 7, 14 cm. The distance from the accelerator window of 10.8 cm and the beam repetition rate of 10 Hz (beam power of 47 W) were set for this part of the experiment. The electron energy of 5 MeV was used. Determination of the dose distribution was done by B3 Radiochromic Film Dosimeters [5], which were calibrated by Risø calorimeters for the electron energy of 5 MeV. The relationship between the response of a B3 foil dosimeter, (in the form of specific absorbance of light) and the absorbed dose was determined. Dosimeter absorbances have been evaluated by Genesys 20 spectrophotometer and the final absorbed doses have been calculated. In the Fig.1 and Fig.2 there are shown results of the dose distribution measurements.

3. Results

As it can be seen in the Fig.1 and also in the Fig.2 all measured points were fitted by Gaussian distribution (normal distribution, Eq. (1)) due to the character of interaction of electrons with matter. It is known that interaction of electrons with matter is highly accidental process and accidental processes like this can be very effectively approximated by Gaussian distribution:

$$y = y_0 + \left(A \times e^{-\frac{1}{2}\left(\frac{x - x_c}{\sigma}\right)^2} \right) \quad (1),$$

where$y_0$is the offset, *A* is the height of the curve peak, *xc* is the position of the centre of the peak and $\sigma$is standard deviation which controls the width of the curve.

In the Fig.2, we can see, that the Gaussian curves are for the all longitudinal distances approximately the same, thus it can be assumed, that distribution of a dose along a scanning electron beam is homogenous. To evaluate homogeneity of a dose distribution in direction perpendicular to direction of the scanning beam, broadening of the electron beam has been studied. The parameter which we were interested in (to evaluate broadening) was the width of the Gaussian curve. The width of the Gaussian curve is represented by parameter σ - standard deviation. Standard deviation in statistics is used to describe how wide is the range of measured values. In our case, distribution of values is distribution of the dose. Figure 3 shows the dependence of the σ on the distance from the window of the accelerator. This dependence is approximately linear. Thus, if the broadening of the electron beam is changing linearly when passing through the air, it can be assumed that the dose distribution in direction perpendicular to direction of the beam scanning is homogenous as well.

If there is a requirement for irradiation of small samples in units of centimetre and smaller, it is appropriate to irradiate them without movement. It means in static mode. To ensure homogenous irradiation, acquired dose cannot differ more than 5% from the maximum dose in determined distance from window of the accelerator. To determine width of the object for homogenous irradiation, it is necessary to calculate the range on which the dose does not differ more than 5 %, 2 % or 1 %. At first, we determined the maximum of the Gauss dose curve (Fig. 1), for each distance from accelerator window. Then we calculated the value of the dose lowered by 1 %, 2 % and 5 %. Finally we assigned the distance from the beam centre to the calculated value of dose. Based on this distance we determined the maximum width of sample irradiated in static mode with required homogeneity. Moreover, we did the calculation for various distances from accelerator window and determined how the maximum width increases with distance from the window of the accelerator. Final result is the dependence of a sample width irradiated homogenously on the distance from the exit window of the accelerator (Fig.4).

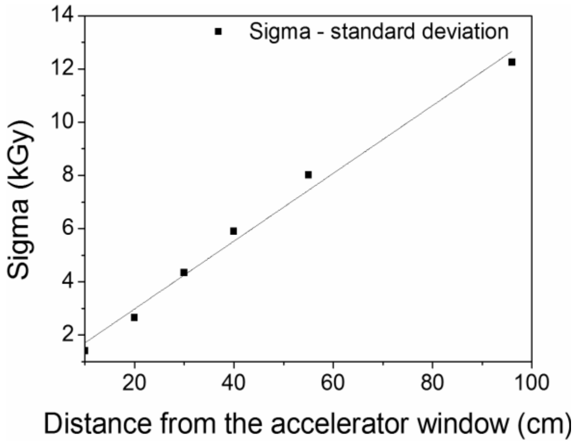

Fig. 3:*Graph of the σ depending on the distance from the window of the accelerator.*

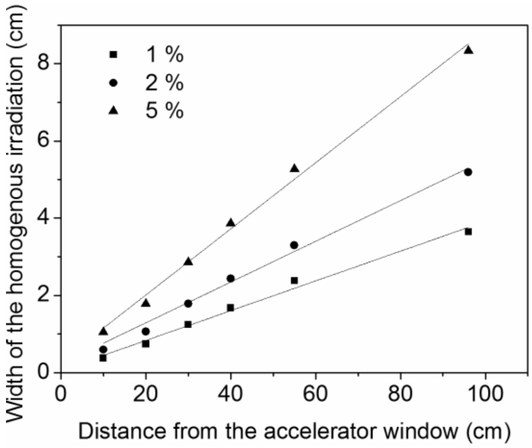

Fig.4: *Dependence of object´s maximum width on the distance from the window of accelerator. The object absorbed dose differs in 1 %, 2 % and 5 % of maximum dose.*

4. Conclusion

Electron beam radiation is very effective and useful tool for radiation processing that finds its applications in medicine, industry and research. Some of the applications have been fully developed for commercial use and some of them still need research and technical realization. Measurement of the dose distribution along a scanning beam and in direction perpendicular to direction of beam scanning for various distances from the accelerator window allowed determination of width of the object that can be statically irradiated at UELR-5-1S accelerator in Trenčín. Stationary irradiation of small samples is very effective and practical. We have determined the maximum width of a sample, suitable for static irradiation, depending on the distance from accelerator window with guarantee of homogenous irradiation within 1 %, 2 % or 5 %.

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