DEPTH DOSE DISTRIBUTION OF THE BREMSSTRAHLUNG GENERATED BY THE BETATRON OB-4 IN DIFFERENT ENVIRONMENTS

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Abstract

In the paper the dosimetric parameters measurement technique of the bremsstrahlung generated by betatron OB-4 is described. The radiation dose measurement results from the bremsstrahlung generated by betatron are shown. The depth dose distributions of the bremsstrahlung generated by betatron obtained with the help of the solid thermoluminescent detectors DTL-02 and the dosimeter UNIDOS E equipped with a PTW Farmer cylindrical ionization chamber type 30013 in the different environments (in the air, in the water and in the lead) are illustrated.

INTRODUCTION

Within a research framework of the development of the new methods to reduce radiation doses for the objects under radiographic analysis, it was proposed to use the pulsed irradiation source synchronized with the detecting device. Such X-ray visualization setups based on the pulsed X-ray generator RAP-160-5 were created in the Department of Applied Physics of the Tomsk Polytechnic University. The previous tests showed a significant radiation dose decline to the objects in comparison with conventional techniques [1, 2]. For estimation of the suitability of using the portable betatron OB-4 as a source of bremsstrahlung for visualization purposes it is necessary to investigate the dosymetric parameters of the device.

The research objectives are:

- to obtain the depth dose distribution in the air, lead and water of the pulsed bremsstrahlung generated by the betatron OB-4;
- to analyse the suitability of using the compact pulse betatron OB-4 as a source of bremsstrahlung for visualization purposes.

MATERIALS AND METHODS

Emitting source

The portable betatron OB-4 was used as a source of emission. This betatron is used as a pulsed source of bremsstrahlung. The material of the target is tungsten (0.6 cm thick). The maximum kinetic energy of the electrons is 4.0 MeV.

The general quantities of the portable betatron OB-4 are: the frequency of radiation impulse is 400 Hz; the duration of one pulse is about 15 µs [3].

Dosimetric equipment

The main problem associated with the dosimetry of the pulsed radiation is the response rate of the dosimeters. This problem can be solved by using the storage type of the detectors. The solid thermoluminescent dosimeters DTL-02 were used as dosimetric equipment for initial estimation of the radiation doses. The thermoluminescent material of the detectors is LiF: Mg, Ti. The dosimetric complex based on the thermoluminescent dosimeters DTL-02 is designed for the personal dosimetry. The dosimeters DTL-02 can work in the energy range of gamma radiation from 15 keV to 10 MeV, the dose range varies from 20 µSv to 10 Sv [4].

The dosimetry protocol for megavoltage photon beams (with nominal energies between 1.25 and 50 MeV) adopted by the AAPM is recommended to use the ionization chambers as the basis for measurements [5]. The universal dosimeter for radiation therapy and diagnostic radiology UNIDOS E equipped with a PTW Farmer chamber type 30013 was used in the experiments [6, 7].

The PTW Farmer cylindrical ionization chamber type 30013 is used for absolute photon and electron dosimetry. This chamber is waterproof and can be used in water phantoms. The main parameters of the cylindrical ionization chamber type 30013 are: the nominal photon energy range is from 30 keV to 50 MeV; the electron energy range is from 10 MeV to 45 MeV; the dose range varies from 0.1 mGy to 1 Gy; the sensitive volume is 0.6 cm^3 [7].

Experimental setup

The irradiation scheme is shown in the figure 1. The irradiation source (1) was placed in lead dome (2) with the output window. The detector (3) was positioned on the radiation axis opposite the output window.

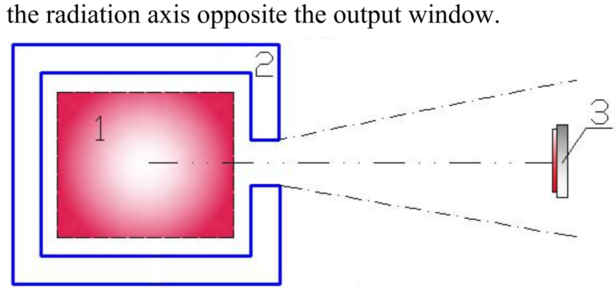

Fig. 1. The irradiation scheme: 1 – the portable betatron OB-4; 2 – the lead dome; 3 – the plane-parallel ionization chamber type 23342

For obtain the depth dose distribution in the lead of the bremsstrahlung generated by the betatron OB-4 the lead plates with the different thickness (0.3, 0.6, 0.8, 5.0 cm) was used.

For obtain the depth dose distribution in the water of the bremsstrahlung generated by the betatron OB-4 the

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water phantom 41023 for horizontal beams was used. The external phantom dimensions are approximately $30 \times 30 \times 30\ \text{cm}^3$. The entrance window in one of the walls has the thickness of 3 mm (the walls material is PMMA) and the size of $150 \times 150\ \text{mm}^2$ [8].

Depth dose distribution technique of the pulsed bremsstrahlung of the betatron

According to the experimental setup the thermoluminescent detectors and the cylindrical ionization chamber were used for the dose measurements of the pulsed bremsstrahlung generated by betatron.

The thermoluminescent dosimeter DTL-02 was used for the dose measurements in the air of the pulsed bremsstrahlung generated by betatron. The measurements were carried out by three different DTL-02 dosimeters at the equal distance between the radiation source and the detector. The dose rate values were calculated.

In the second part of the experiment the dose and the dose rate measurements in the three different arias: in the air, in the lead and in the water were carried out by the universal dosimeter UNIDOS E equipped with the cylindrical ionization chamber type 30013.

The measurement mode of the dosimeter UNIDOS E was “LOW”. The dose rates measurement operating mode of the ionization chamber type 30013 is 0.6 mGy/min – 0.5 Gy/min [7]. The cylindrical ionization chamber type 30013 was used with the special buildup cap.

In the experiment in the air the distance between the radiation source and the detectors was varied from 30 to 100 cm in increments of 10 cm.

For obtain the depth dose distribution in the lead of the bremsstrahlung generated by the betatron OB-4 the lead plates were arranged on the radiation axis close by the output window, the detector was positioned opposite the lead plates.

For obtain the depth dose distribution in the water of the bremsstrahlung generated by the betatron OB-4 the water phantom 41023 for horizontal beams was used. The phantom arranged on the radiation axis opposite the output window at the distance equal to 50 cm, the detector was positioned inside the phantom. Because of the water phantom plastic wall is greater than 0.2 cm thick, all depths was scaled to water-equivalent depths. For a PMMA wall, in photon or electron beams the effective wall thickness is given by the measured thickness in cm times 1.12 [5].

RESULTS AND DISCUSSIONS

In the Fig. 2 the dose rate distribution in the air of the pulsed bremsstrahlung generated by betatron depend on the distance between the betatron OB-4 and the detector using the solid thermoluminescent dosimeters DTL-02 and the cylindrical ionization chamber type 30013 are presented. The dose rate measurement for the different distance between the radiation source (betatron) and the detector are average over three different DTL-02 dosimeters.

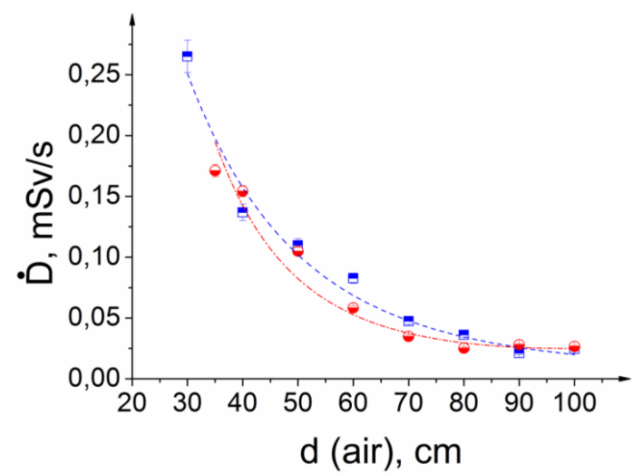

Fig. 2. The depth dose distribution in the air of the pulsed bremsstrahlung generated by betatron: ▬ – the solid thermoluminescent dosimeters DTL-02 measurement results; – – – - the approximation results of the solid thermoluminescent dosimeters DTL-02 measurements; ● – the cylindrical ionization chamber type 30013 measurement results; –·–·– - the approximation results of the cylindrical ionization chamber type 30013 measurements.

The Fig. 2 shows that the dose rates measurement obtained using the thermoluminescent detectors and the cylindrical ionization chamber are in a good agreement with each other. These points to the fact that the cylindrical ionization chamber can be used for routine dosimetry of the pulsed bremsstrahlung generated by betatron.

The insignificant divergences between the obtained curves in the Fig. 2 can be explained by the fact that there are some angular divergence of the betatron beam and dispersion of the high-energy part of the gamma spectrum. In this case, it is proposed to use the collimator for future dosimetry measurements. Nevertheless, it is evident that the obtained dependences are well approximated by exponential curves. That is in agreement with the theory.

The obtained data (Fig.2.) shows the sufficient equability of the accelerator beam, which indicates the suitability of the betatron OB-4 for the visualization purpose.

The depth dose distribution in the lead and in the water of the pulsed bremsstrahlung generated by betatron obtained with the help of the cylindrical ionization chamber type 30013 are presented in the Fig. 3 and the Fig. 4 correspondingly.

The profile of the depth dose distribution in the lead (Fig.3.) has an enough linear character for the adsorber thickness up to 3 cm, which indicates the suitability of the accelerator in the nondestructive testing goals.

The profile of the depth dose distribution in the water (Fig.4.) has a linear character and demonstrates the suitability of the pulsed bremsstrahlung generated by betatron OB-4 for visualization biological objects with

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thicknesses up to 25 cm, which is typical of the human body size.

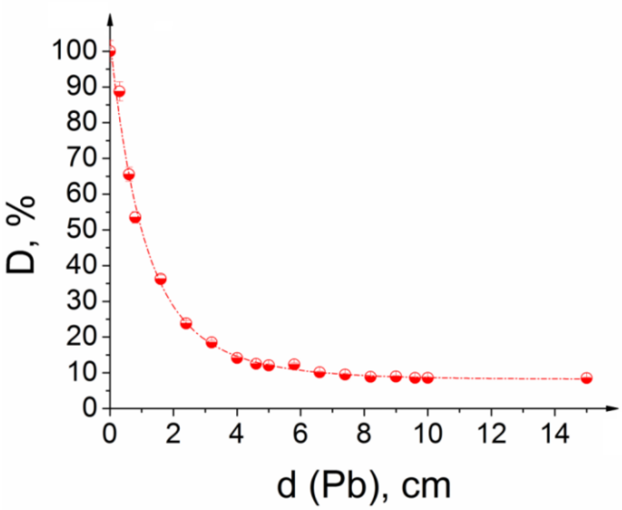

Fig. 3. The depth dose distribution in the lead of the pulsed bremsstrahlung generated by betatron: – the cylindrical ionization chamber type 30013 measurement results; - the approximation results of the cylindrical ionization chamber type 30013 measurements.

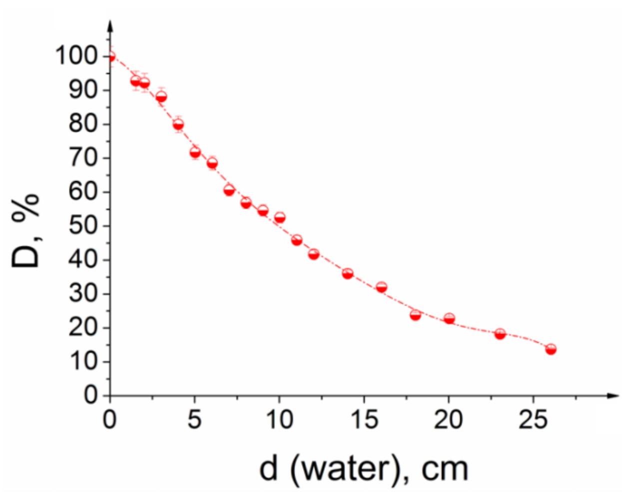

Fig. 4. The depth dose distribution in the water of the pulsed bremsstrahlung generated by betatron; – the cylindrical ionization chamber type 30013 measurement results; - the approximation results of the cylindrical ionization chamber type 30013 measurements.

SUMMARY

The obtained date show the advisability of using the solid thermoluminescent dosimeters DTL-02 and the universal dosimeter UNIDOS E equipped with a PTW Farmer chamber type 30013 for the dosimetric parameters measurements of the pulsed bremsstrahlung generated by electron accelerator with energy of 4 MeV.

After the dosimetric equipments selection the radiation dose of the pulsed bremsstrahlung generated by betatron OB-4 was estimated. The obtained data show that the bremsstrahlung generated by betatron OB-4 can be used for the visualization purposes of the objects in the nondestructive and medical examinations.

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