**DEVELOPMENT AND OPTIMIZATION OF TUNGSTEN MATRIX COLLIMATORS FOR SPATIALLY FRACTIONATED RADIATION THERAPY**

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Spatially fractionated radiation therapy is a promising method of treating cancer, which allows to reduce the dose load on healthy tissues. This method is based on the use of spatially modulated radiation fields, which are created by scanning micro-beams of hadrons or using special collimators. The key element of PFRT in the second method is matrix collimators, which form the dose field with the formed mini-beams according to the design of the matrix collimator.

The main idea of ​​PFRT is to create a non-uniform dose distribution with areas of high and low intensity of the irradiating beams. This allows to achieve a high dose in the tumor, with a reduced load on

healthy tissues. The effectiveness of this approach is based on the different radiosensitivity of normal and tumor cells, as well as the ability of healthy tissues to recover when receiving a non-uniform dose [1].

Optimization of the geometry and material of collimators is an important task to increase the effectiveness of treatment. The quality of beam fractionation, which directly affects the therapeutic effect, depends on the choice of material, collimator thickness, hole sizes, and their mutual arrangement. Therefore, the study of optimal collimator parameters is an urgent task for the development of PFRT methods.

The study included computer modeling and experimental studies. Experimental studies were conducted on a medical accelerator LINAC with a typical therapeutic energy of 6-25 MeV. The distance from the accelerator to the collimator was 1 m. The experiment was aimed at studying the efficiency of fractionation of a beam of gamma quanta with an energy of 6 MeV by a metal collimator. The intensity distribution of the mini-beams of photons created by the collimator was measured by a micro-pixel detector TIMEPIX (Collaboration MEDIPX, CERN) with a sensitive area of ​​14 x 14 cm2 (256 x 256 pixels with a size of 55 x 55 μm2). The segmentation of the detector allows obtaining a two-dimensional image of the beam profile in real time [2].

Two types of collimators were used for beam fractionation: brass and lead. The brass collimator was 2 cm thick and contained 6 slits 1 mm wide with a distance between the centers of adjacent slits of 2.5 mm over an area of ​​30x30 cm². The lead collimator is an assembly of 3 mm thick plates with a 5×5 hole matrix, 1 mm in diameter and 3 mm in pitch.

To assess the efficiency of fractionation, Monte Carlo simulations were performed in the GEANT4 and FLUKA (CERN) software packages. These run-of-the-mill codes allow modeling the passage of ionizing radiation through matter, taking into account all physical interaction processes.

In particular, the simulations considered a phantom model in the form of a 10×10×10 cm3 cube made of Plexiglas, which imitates biological tissue. A 4×4 cm2 tungsten collimator with a length of 9-12 cm was located in front of the phantom. A 5×5 hole matrix with a diameter of 1 mm and a distance between the hole centers of 3 mm was simulated in the center of the collimator.

Simulations were performed for two types of radiation:

- Gamma quanta with an energy of 25 MeV, which corresponds to the maximum energy used in modern radiotherapy.

- Electrons with an energy of 18 MeV, which is a typical energy for electron therapy.

For each type of radiation, simulations were performed for different collimator thicknesses in order to determine the optimal parameters. Characteristics such as dose distribution over depth, beam profile at different depths, peak-valley dose ratio (PVDR), and the contribution of secondary particles to the formation of the dose field were evaluated.

Experimental studies and Monte Carlo simulations have confirmed the possibility of achieving high fractionation rates (PVDR > 10) for gamma rays and electrons when using tungsten collimators of optimal thickness. This indicates the promising application of PFRT for the treatment of superficial neoplasms.

However, a rapid decay of the fractionation effect with depth was found, which limits the application of the method for deeply located tumors. This indicates the need for further research to develop methods for preserving the structure of the fractionated beam at greater depths.

The proposed design of a modular tungsten collimator allows for flexible adjustment of its parameters under different irradiation conditions, which is promising for further research and clinical application of PFRT. Such a design can become the basis for creating adaptive irradiation systems that will optimize the dose distribution for each specific patient.

The results obtained can be used in the design of new collimators with increased efficiency of therapeutic beam formation. They also provide important information for the development of treatment protocols using PFRT.

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| a | b |
| Distribution of the delivered dose in the collimator, the surrounding environment and the phantom along a beam of gamma rays with an energy of 25 MeV (a), electrons with an energy of 18 MeV (b) | |

Further research will be aimed at experimentally verifying the developed models and assessing their impact on the dose distribution in PFRT. An important direction is also the search for ways to increase the depth of effective fractionation, which may include the use of combined irradiation methods or the development of new materials for collimators[3-5].

Further work will be devoted to the study of tungsten activation under the influence of ionizing radiation.

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1. Yan, W., Khan, M. K., Wu, X., Simone II, C. B., Fan, J., Gressen, E., ... & Mourad, W. F. (2020). Spatially fractionated radiation therapy: History, present and the future. Clinical and translational radiation oncology, 20, 30-38. <https://doi.org/10.1016/j.ctro.2019.10.004>
2. Pugatch, V., Campbell, M., Chaus, A., Kovalchuk, O., Llopart, X., Okhrimenko, O., ... & Tlustos, L. (2012). Metal micro-detector TimePix imaging synchrotron radiation beams at the ESRF Bio-Medical Beamline ID17. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 682, 8-11. https://doi.org/10.1016/j.nima.2012.03.049
3. Ramazanov, D. M., & Anokhin, I. E. (2023). Monte Carlo simulations of tungsten array collimators for spatially fractionated radiation therapy. In Scientific Bulletin of UNFU (Vol. 33, Issue 5, pp. 70–76). Ukrainian National Forestry University. https://doi.org/10.36930/40330509
4. Ramazanov, D., & Anokhin, I. (2023). DEVELOPMENT OF A TUNGSTEN MATRIX COLLIMATOR FOR ELECTRONIC SPATIALLY FRACTIONATED THERAPY. In Science and Technology Today (Issue 12(26)). Ukrainian Assembly of Doctors of Science in Public Administration. https://doi.org/10.52058/2786-6025-2023-12(26)-626-636
5. Anokhin, I., & Ramazanov, D. (2023). Matrix metal collimators studies for the spatially fractionated radiation therapy. In COMPUTER-INTEGRATED TECHNOLOGIES: EDUCATION, SCIENCE, PRODUCTION (Issue 53, pp. 5–8). Lutsknational Technical University. https://doi.org/10.36910/6775-2524-0560-2023-53-01