ELLUS-6M LINEAR ELECTRON ACCELERATOR FOR RADIOTHERAPY

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Abstract

"ELLUS-6M", a compact medical accelerator of new generation, has been designed and manufactured for radiotherapy by 6MeV photons in the multi-static and arc modes. The gantry of the accelerator can be rotated through $\pm 185^0$ and ensures setting accuracies of the irradiator rotation velocity and positioning sufficient for the IMRT mode. The computerized control system is compatible with the treatment planning system and allows upgrading by adding new modules.

To realize the conformal radiotherapy, the following additional medical equipment has been developed: a multi-leaf collimator, a portal vision system for the dose field verification during irradiation and an upgraded treatment table made as a semi-pantograph.

In 2010, it is planned to finish clinical tests of the "ELLUS-6M" accelerator with the additional medical equipment carried out in the N.N. Petrov Scientific Research Oncology Institute, Pesochny, St.Petersburg.

In countries with a highly-developed economics, radiotherapy is used for treatment of more than 70% of oncological patients, and more than 60% of such patients are usually successfully cured of cancer. In Russia, this method is used for treatment of less than 20% of the whole number of oncological patients, which mainly depends on insufficient up-to-date radiotherapeutic equipment available in oncologic institutions in our country Linear accelerators, which can be used for the conventional beam therapy, are about 80 in number, and only 20 machines are used for the conformal treatment. It is highly insufficient to satisfy the needs for these machines; for comparison, the international standards are 1 machine for 250-300 thousand people.

Nowadays in Russia have appeared all necessary prerequisites to change critically the status of radiotherapy. The Government of the Russian Federation has taken a decision on the financial support of activities aimed at the advancement of oncological treatment of the population and fitting out of oncological clinics with up-to-date equipment.

Development of electrophysical equipment for radiotherapy is one of high-priority lines of activity of FSUE "D.V. Efremov Scientific Research Institute of Electrophysical Apparatus". Several generations of accelerators and cyclotrons for medicine have been developed since the foundation of the Institute [1, 2]. A new generation of linear electron accelerators for radiotherapy has been developed by specialists of the Institute, one of these machines is a 6 MeV "ELLUS-6M" shown in figure 1.

Figure 1: The "ELLUS-6M" accelerator under technical tests; dose fields are being measured in a water phantom

The new accelerator is equipped with a computerized control system, demountable multileaf collimator to form bremsstrahlung fields with a high accuracy and a portal image-based verification system. The system for radiotherapy developed on the basis of the "ELLUS-6M" accelerator allows the most advanced technologies of the radiation oncology to be realized.

The main block of the accelerator is an irradiator, which includes systems and units for an electron beam generation and acceleration, its transport and forming in compliance with a particular treatment plan, as well as dose monitoring and verification of treatment prescription.

The beam is generated in a three-electrode electron source and injected into the accelerating structure, which is a chain of coupled cavities. A standing-wave accelerating structure is used in the "ELLUS-6M" accelerator. Simultaneously, the RF energy is supplied to the accelerating structure by a magnetron via the waveguide line.

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From the accelerating structure, electrons reach a deflection-focusing system where they are deflected by a magnet to an angle of 130° and focused to a tungsten target. Rectangular radiation fields, which are necessary for radiotherapy, are formed by radiation head collimators.

The irradiator can be rotated through an angle of $\pm 185^0$; the servo drive of the gantry ensures variation of angular velocity and necessary irradiator positioning accuracy.

Mechanical travels of the gantry, radiation head and treatment table can be controlled both from the manual control console and automatically from the host computer located in the control console room.

The computer control system supports DICOM 3, DICOM RT and HL4 communication protocols with the treatment planning and topometric systems.

The accelerator is also equipped with a multileaf collimator (see Fig. 2, 3), which allows individual radiation fields to be formed (see Fig. 4).

Figure 2: Multileaf collimator mounted on the SL-75-5 accelerator

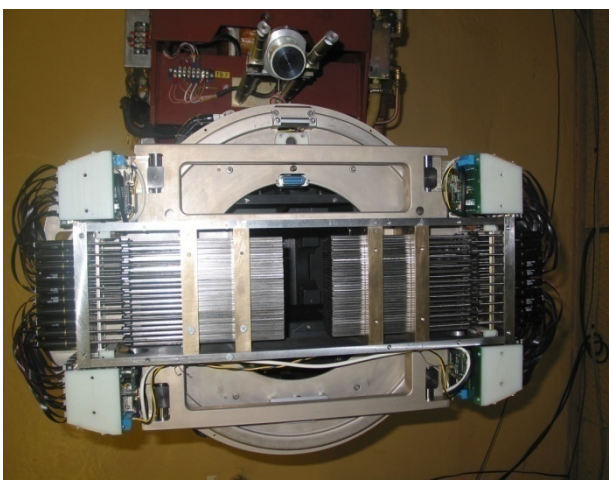

Figure 3: Multileaf collimator without casing

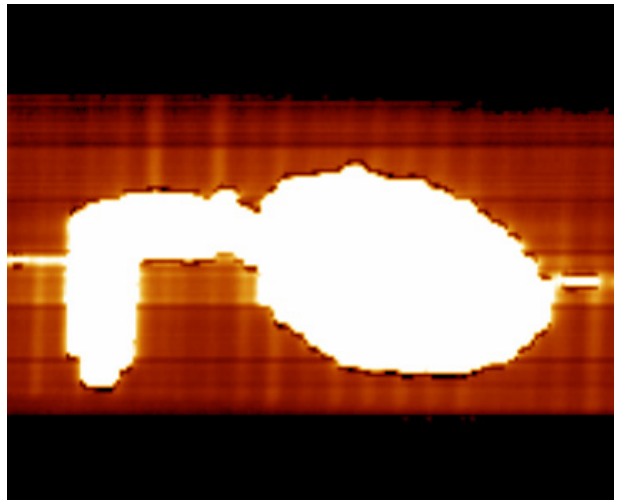

Figure 4: Radiation fields of required configuration formed with the MLC; the field image is obtained by using the portal image-based verification system

Prior to irradiation with an irregular field, an anatomic and topometric preparation is done with an X-ray topometric system TSR-100 [3], which is a component of the radiotherapeutical system developed in NIIEFA.

Fig. 5 shows the preparation of a patient for treatment. On the image of a patient's body a radiologist chooses an area to be treated (on the right of the figure); after that the treatment planning system performs computations of the leaves' position, which most accurately describes a preset contour (on the left of the figure). The data file comprising coordinates of the leaves is transferred to the MLC control system of the accelerator. In the process of patient's set up, the portal image system is used to verify the accuracy of the formed radiation field and the coincidence of the planned treatment area with the actual patient treatment position.

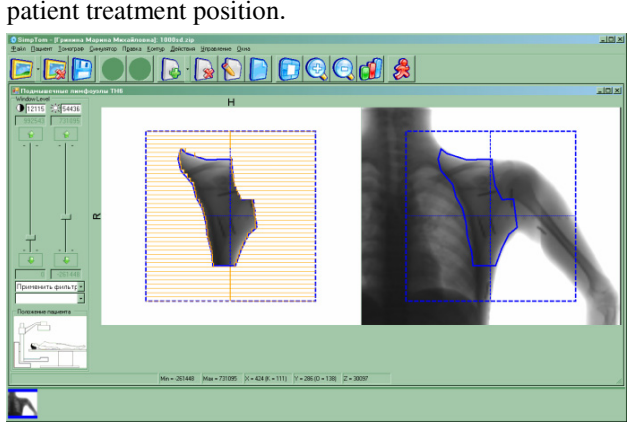

Figure 5: Irregular field chosen for treatment by a radiologist on the basis of a patient body projection image (right) and computations of MLC leaves' coordinates (left)

The collimator is a demountable device; it is so mounted on the accelerator radiation head so that to keep the possibility of the radiation head to rotate around the central axis of the beam. The collimator drive ensures independent travel of leaves and verification of their

position. The width of the area covered with one leaf is 0.5 cm 1m from target. The transmission between the ends of the closely connected leaves is less than 50% and between the neighboring leaves is 5%.

The MLC leaves' positioning system ensures the formation of the field boundary 1 m from target accurate to not worse than ±1mm. Depending on the leaf position, the penumbra width changes less than for 3 mm.

The MLC developed can also be used with SL-75-5 accelerators for conformal and IMRT irradiation techniquesIn addition to the MLC, the accelerator is equipped with an independent patient treatment prescription verification system, which allows us to verify the compliance with the treatment prescription of the patient position relative to the beam of the accelerator.

The portal image device is an advanced tool contributing to higher efficiency of radiotherapy due to verification of the most important stages of the treatment process, namely a patient's set up and radiation field formation.

The portal image-based verification system is located directly on the rotating gantry of the accelerator (see Fig. 6). The system visualizes projected images of a patient's treatment position by recording the beam passing through the body of the patient (the portal image device). The dose field verification system developed for the "ELLUS-6M" accelerator can also be used on SL-75-5 accelerators.

As an example, Fig. 7 shows an image of a calf head obtained with the TSR-100 topometric system by using the beam of the SL-75-5 accelerator.

Figure 6: The portal vision system with beam-forming block

The delivery set of the "ELLUS-6M" accelerator includes a treatment table. The table top vertical travel is from 650 up to 1900 mm (above the floor); the table top horizontal longitudinal travel is 800 mm and its transversal travel is ±200 mm. The table can be rotated around the vertical axis passing through the isocenter for $\pm 95^0$.

The treatment table travels are actuated by servo drives with a smoothly regulated velocity. The table travels can be controlled both manually from a local control desk and automatically from the accelerator control system.

The table top is equipped with components to secure fixing accessories. On both sides of the table top, universal rails are made and emergency-off buttons for the whole radiotherapeutic facility and to stop the table traveling are located.

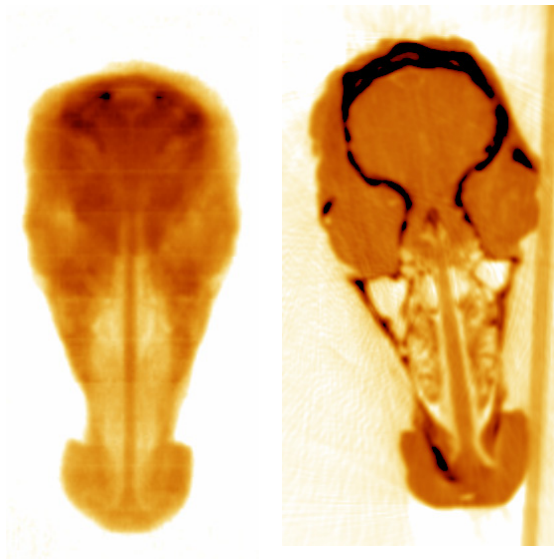

Figure 7: Calf head as a tested object.The image obtained with the therapeutic beam of the SL-75-5 accelerator (left) and a longitudinal tomogram obtained on the TSR-100 topometric system (right)

In addition, the accelerator is equipped with laser isocentor pointers, a TV treatment-room monitoring system and an intercom. The delivery set in addition to the accelerator includes the equipment necessary for maintenance/repair works.

So, the radiotherapeutic system on the basis of the linear electron accelerator "ELLUS-6M" equipped with the multileaf collimator, portal vision system for treatment verification, treatment table and other auxiliary devices allows the main problems of radiotherapy to be successfully solved satisfying the requirements of modern beam therapy techniques.

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