X-RAY RADIATION HIGH-VOLTAGE ELEMENTS OF THE TANDEM ACCELERATOR WITH VACUUM INSULATION

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Abstract

In Institute of Nuclear Physics SB RAS the epithermal neutron source is entered into operation based on the tandem – accelerator with vacuum isolation. There was evaluated the accelerating installation components of a x-ray field causing dark current and breakdowns in accelerating gaps. The estimated account of equivalent doze capacity on different distances from the accelerator in the protected hall and behind its limits is made.

The experimental measurements were carried out and the study results of the doze capacity dynamics are submitted, depending on change of a dark current in tandem accelerating gaps at a complete working voltage 1 MV without a beam. The spectrum of x-ray radiation is experimentally measured. It is experimentally revealed and the occurrence of powerful X-ray radiation is investigated at substantial growth of the aperture of the accelerating channel. The design changes of installation for prevention of occurrence of powerful X-ray radiation are offered and realized.

The carried research allows setting necessary parameters for designing medical installation on the basis of an accelerator - tandem with vacuum isolation with the purpose of realization in oncological clinics neutron-capture therapy of malignant tumors.

INTRODUCION

In the BINP, the prototype of epithermal neutrons source in an innovative high-current tandem accelerator with vacuum insulation has been proposed [1] and constructed [2]. It is attractive to be accommodated in oncological clinics for carrying out boron neutron capture therapy of malignant tumors.

In the high-voltage vacuum components of the installation, electrons of auto emission and discharge origin, which are the basic elements of the parasitic "dark" current [3] and are accelerated in a vacuum gaps, emit X-rays after braking at the electrodes, which is the main source of radiation hazard in operation without the accelerated charged particles beam. The study of the unused X-ray field of the installation and the method to reduce its radiation hazard to an acceptable level is an urgent task, as the accelerator is being developed for medical purposes.

EXPERIMENTAL MEASUREMENT OF X-RAYS LEVELS ON THE INSTALATION

For operational monitoring of X-ray radiation levels around the experimental installation and for its biological defense, tandem is equipped with automatic radiation monitoring system (provided services) [4], developed in BINP.

Dose rate measurements of photon radiation in the system are carried out by four detecting units (Fig. 1),

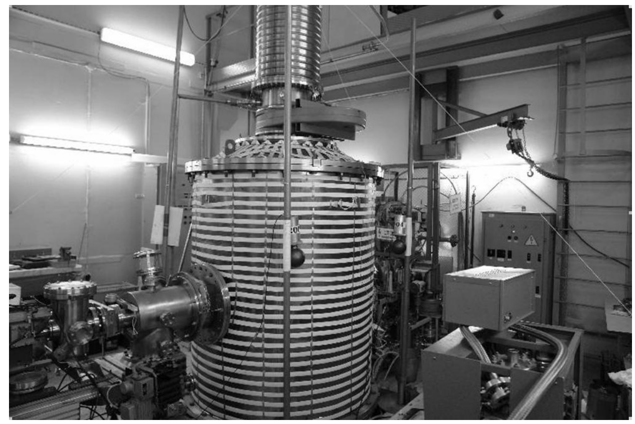

Fig. 1. Placement detection units around the accelerator.

Fig.2. Detection unit dose power of photon radiation.

based on the spherical ionization chambers (Fig. 2) with an air-filling 0.85 liter volume and with a thickness of polyamide wall about 1.1 mm, coated with a thin layer colloidal graphite.

Using the organic dielectric, as a wall material, can reduce overall dimensions and weight of the detector and can help to avoid significant deterioration in the camera's sensitivity to low-energy radiation. The dynamic range of the detector is - 1 ÷ 12 000 mcSv/h.

To determine the uniformity level of X-ray radiation in the azimuth plane, around the accelerator at a distance of

ISBN 978-3-95450-125-0

1 m from the external surface of the tank there were placed four detection units through 90°. After the data record, all the blocks were shifted by 45° and measurements were repeated. To filter out the values, clearly associated with the breakdown and pre-breakdown currents, which can be determined by voltage divider indications of the high-voltage source and the insulator, by a sharp deterioration of the residual vacuum in the tandem, by a throws of dark current I and X-ray dose power D (Fig. 3)[5].

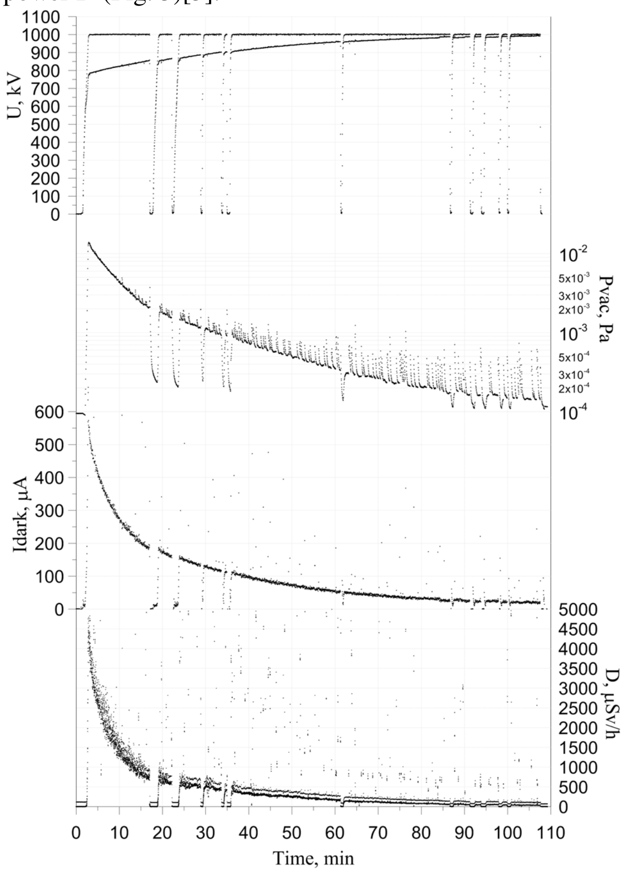

Fig.3. Typical graphics of the voltage, vacuum, dark current and dose X-rays with the 4 detectors on time.

The results of X-rays measurements in all the experiments were processed by using the software implemented algorithm of statistical data processing.

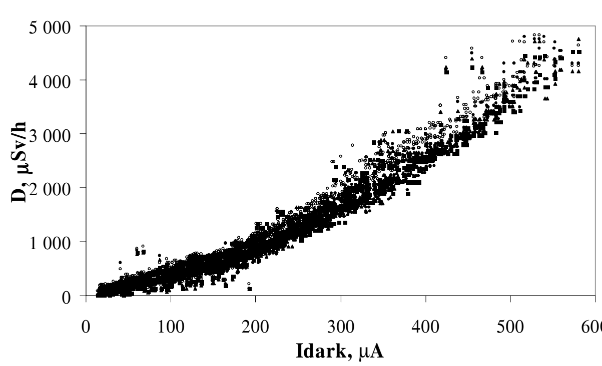

Fig. 4. Dependence of X-rays on the value of the dark current.

Fig. 4 shows the dependence of the X-ray power dose of all four detectors on the dark current. It can be seen, that with good accuracy the radiation power is proportional to the dark current. Fig. 5 shows the average measured values from three consecutive experiments for the dark current values I = 300 ± 10 mA and the voltage on the high-voltage electrode 1 MV. It can be seen, that the radiation can be considered uniform within 20%, which means a relatively uniform distribution of dark currents on the electrode surfaces.

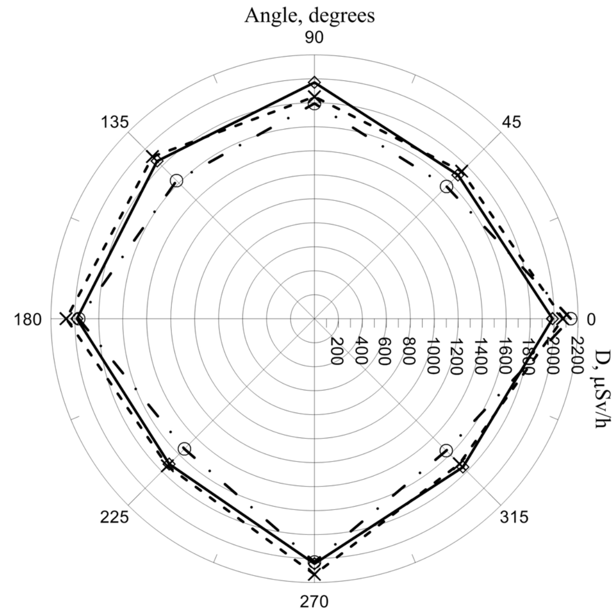

Fig.5. Angular distribution of the X-ray radiation accelerator.

The measurement results of the X-ray intensity by sensors, located at 2, 3.3 and 4.2 m from the center of the accelerator in the horizontal plane at the center height of the accelerator, are in agreement with the calculated, assuming a point source, with an accuracy ~ 8%. This result confirms the relatively even distribution of dark currents on the electrode surface.

The experiments have showed, that for training time ~ 1 ÷ 2 hours, the level of X-ray field is greatly reduced. Thus, at a distance of 2 m from the accelerator, X-ray dose is reduced from 1000 mcSv/h to ~ 10 mcSv/h. The vacuum value of ~ 10^{-4} Pa. Dynamics of changes in the dark current showed that the main cause of its occurrence is the gas desorption from the tank and electrode surfaces. To reduce output time to a safe level of the X-ray radiation it is necessary to increase the vacuum pumping speed.

ENERGY SPECTRUM OF X-RAY RADIATION

With using BGO-spectrometer, installed inside the protected room at a distance of 6.3 m from the center of the accelerator, the X-ray energy spectrum was measured (Fig. 6). At the moment of the spectra measurement, the residual gas pressure was 4 10-4 Pa, dark current value

ISBN 978-3-95450-125-0

was 65 ± 3 mA, and the ionization chamber registered the dose 34 ± 4 mcSv/h at the distance of 4 m. This spectrum confirmed well the initial data point, that achieved electron energy must not exceed the value of 200 keV, determined by the difference in potential between adjacent electrodes accelerating gaps.

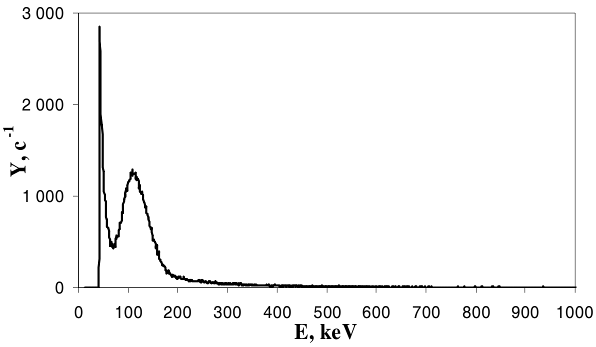

Fig. 6. Measured energy spectrum of X-rays.

THE DARK CURRENT OF GREAT INTENSITY AFTER INCREASING APERTURE ACCELERATING CHANNEL

Following an increase in the aperture of the accelerating channel up to 58 mm there was recorded the dark current 3 - 4 mA [6] with a much greater intensity of radiation than dark currents studied in [3] and described above. In [6] it is found that increasing the diameter of the aperture increases the electric field strength at the sharp edge of the cathode frame hole of the mounting aperture. Electrons, emitted from the sharp edge, pass directly into the acceleration channel. The measured energy spectrum of the X-ray emission during the flow of the current high intensity is shown in Fig. 7. It can be seen that the distribution shifted to larger values of the photon energy, which confirms the conclusion made in [6], that the emitted electrons enter the accelerating channel and accelerated up to full voltage. It should be noted, that in comparison with the conditions of the experiment, described in [3], the diameters of the intermediate electrode diaphragms, which are the accelerating channel of the negative hydrogen ions, are not 58 mm, and gradually decreasing: 43, 43, 35, 30, 25 and 20 mm, which, perhaps, explains the lower value of the current - about 1 mA.

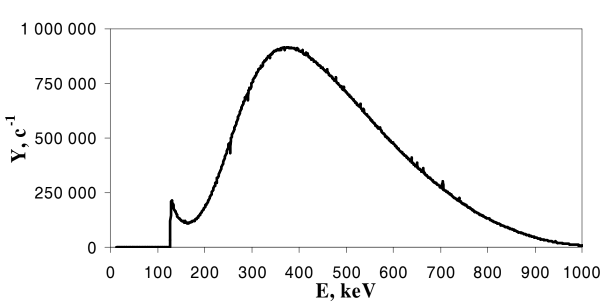

Fig. 7. Measured energy spectrum of the X-ray emission during the flow of the dark current great intensity.

RESULTS AND PROSPECTS

While accelerator training the X-rays dose at different azimuths, heights and distances was experimentally measured. It is found out that the radiation can be considered azimuthally uniform and decreases quadratically with the distance from the center of the accelerator. It is determined, that during accelerator training, the dose rate at a distance of 2 m from the accelerator does not exceed 1000 mcSv/h, and by the end of the training in 1 - 2 hours decreases to about 10 mcSv/h. Behind the existing 122-centimeter concrete wall of radiation-protected room, which houses the accelerator, the dose rate is below the sensitivity limit of the dosimetric devices.

BGO-spectrometer measured the spectrum of X-rays, characterized by energies below 200 keV to 120 keV maximally. This spectrum confirms the assumption, that during the training of the accelerator, the radiation source is dark currents in interelectrode gaps caused by auto electron emission from the surface of the vacuum tank and the accelerating electrodes.

The emergence of powerful radiation at a significant increase in the aperture of the accelerating channel is experimentally observed and studied. The measured X-ray spectrum contains photons with significant energy, up to the energy corresponding to the full voltage of the accelerator. It was determined that the emergence of intense radiation is due to dark current, flowing directly in the accelerating channel and arising with the resulting increase in the aperture of the channel due to the sharp edge hole of the cathode part mounting frame diaphragm. The design of the accelerator has been amended to prevent currents and, as a consequence, high-power radiation.

This study allows setting the required parameters for the design of medical installation based on a tandem accelerator with vacuum insulation to conduct neutron capture therapy of malignant tumors in oncological clinics.

The authors thank V.V. Extra for performing mounting, adjustment and startup of ACPM.

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ISBN 978-3-95450-125-0