EXPERIMENTAL STUDIES INTO SPECTRAL AND TIME CHARACTERISTICS OF THE ACCELERATOR U-12 RADIATION FIELD

A.M. Yegorov, V.Ja. Migalenja, V.I. Nagaychenko, V.V. Sotnikov, V.A. Voronko, V.V. Zhuk
National Science Center "Kharkov Institute of Physics and Technology"
"Institute of plasma electronics and new methods of acceleration", Kharkov, Ukraine;
E-mail: voronko@kipt.kharkov.ua

The present paper is concerned with experimental studies of the structure, time and spectral characteristics of the radiation field of the accelerator U-12. The results obtained from the studies were used to develop the concept of constructing a mobile complex applicable for registration and location of neutron- and gamma-radiations outside the room, which accommodates the accelerator, and also for the assessment of efficiency in radiation shielding of pulsed accelerators.

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In the present work the results of the experimental research of structure, time and spectral characteristics of the pulse radiation fields generated in an operating time of accelerator U-12 are presented. For registration of pulse radiation fields we have applied the standard equipment, as well as the detecting spectrometric equipment we have made ourselves. The obtained results were used for development of the mobile complex applied for registration of neutron and gamma-radiations from the accelerator outside the room, and also for the assessment of the efficiency in radiation shielding of pulsed accelerators. The possibility of obtaining information on the parameters and characteristics of pulsed accelerators from the measurements of neutron- and gamma-radiations behind the shield (without a direct access to the accelerator hall) has been investigated.

1. ACCELERATING STAND U-12

The accelerating stand U-12 is the device at which principles of designing of high-current linear accelerators of protons and negative ions of hydrogen up to energy-100 MeV have been confirmed. It can be considered as an intermediate stand at which the technical equipment for beam acceleration is fulfilled, investigations on distribution of ionizing radiation fields are carried out, applicability of the modified breaking-phase focusing in H-resonators [1] is tested.

Stand U-12 represents electrophysical facility consisting of:

- injector, working in a pulse mode and providing a current of 150 mA with an energy 150 kV;
- the basic section representing the small-sized linear accelerator of protons with an energy of 10 MeV, collected on 3 H-resonators placed in the uniform vacuum casing, with a proton current up to 10 mA;
- the high-frequency supply source of the basic section (3 amplification cascades with output power 1.2 MW, porosity 40 and wave length 2 m);
- systems of diagnostics supervising an operating mode of installation and measuring, as the basic characteristics of a beam (current, energy, emittance, etc.), and a condition of accelerating structure;
- Systems of cooling and exact thermostating the systems of the stand including systems of automatic control of temperature of accelerating sections;
- Systems of a power supply, operating, blocking.

2. RESEARCH OF SPECTRAL AND TIME CHARACTERISTICS OF PULSE γ - RADIATION

Measurements of power distribution of the gamma-radiation accompanying work of the linear proton accelerator, were carried out in a hall and behind biological shield with the help of Ge (Li) detectors with 50 cm^3 and 125 cm^3 crystal volume and NaI(Tl) detector with crystal in the size 150x100 mm. In connection with that at measurement of γ - spectra the spectrometer was in the field of secondary radiation consisting from neutron and a γ - component, modelling conditions of measurements has been carried out. At modelling sources ^{60}Co with intensity of radiation $1.8 \cdot 10^4$ γ /sec, ^{137}Cs ($6.9 \cdot 10^4$ γ /sec) and a neutron source ^{252}Cf with intensity $7.2 \cdot 10^4$ neutron/sec were used. The neutron source placed closely to the detector, and γ - sources on various distance from the detector. The measured γ - spectra has exponential character - result of registration of recoil atoms in a material of the detector. If γ - sources are from the detector on distance less than 50 cm at spectra there are γ - lines ^{137}Cs 661.6 keV and ^{60}Co - 1173.2 and 1332.5 keV, and also a γ - line with energy 388.2 keV, specifying on presence of an impurity ^{249}Cf in a neutron source. In the spectra measured for γ-sources placed at ~50 cm from Ge(Li) - detector, γ - lines ^{60}Co to visualize on a background exponential distributions it is impossible, and γ - line ^{137}Cs are visible well. For this geometry the relation of intensity of γ-radiation to the neutron radiation falling on the detector, makes $1.0 \cdot 10^{-4}$ for ^{60}Co and $3.8 \cdot 10^{-4}$ for ^{137}Cs, i.e. γ-lines are reliably enough visualized on exponential background if intensity γ-radiation makes not less than 10^{-4} from intensity of a neutron flux.

Measurement of a γ- spectra at work of accelerator U-12 in a regular mode were carried out in a target hall of the accelerator on a mark – 1-6 (fig.1). The intensive bremsstrahlung generated by electrons of autoelectronic

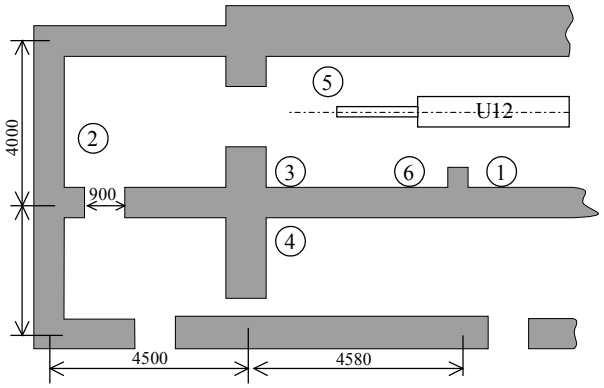

Fig.1. The plan of U-12 accelerator building and mark points of measurement

emission (when input the HF-field in resonators) is the basic difficulty at carrying out of measurements. When all three resonators are switch on with the nominal mode of power, intensity of x-ray radiation is so high, that Ge(Li) and NaI (Tl) spectrometers enter into saturation mode during mark. In such conditions carrying out of γ-spectra measurements in a hall of the accelerator is impossible. Detectors shielding due to neutrons has been executed as a set of coaxial cylinders from paraffin by thickness of 10 cm, cadmium (0.3 cm) and lead (1 mm). Fig.2 shows the γ-spectrum measured at the point 6 of the accelerator hall. The most part of γ - quanta are generated in the neutron reaction with nucleus of the elements included in stainless steel of a vacuum shield of the accelerator. Identification of γ- lines is resulted in table.

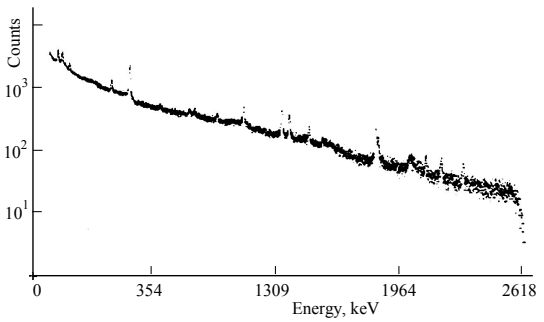

Fig.2. Gamma - spectrum measured in the accelerator hall (point 6, fig.1). Proton beam energy 10 MeV

In spectra measured in an atmosphere behind biological shield of the accelerator (fig.3), the most intensive γ-lines are produced in reaction of radiating capture of neutrons by nucleus of nitrogen. Intensity of the γ-lines corresponding to reaction (n,γ) is proportional to a flux of thermal and resonant neutrons in the given point, as the cross-section of (n,γ) reaction sharply falls with growth of energy of neutrons. Therefore from the γ - lines intensity ratio in the spectra measured in two various points one can obtain the estimation of the neutron flux density ratio in these points. The γ-radiation intensity ratio for the spectra

Identification of γ-lines for spectrum shown in Fig.2

Energy, keV	Reaction
669.0±2.0	$^{63}Cu(p,n)^{63}Zn$
845.7±2.0	$^{56}Fe(n,n'\gamma)^{56}Fe$, $^{56}Fe(n,p)^{56}Mn$
960.3±2.0	$^{58}Ni(n,n'\gamma)^{58}Ni$, $^{63}Cu(p,n)^{63}Zn$
1096.2±2.0	$^{58}Fe(n,\gamma)^{59}Fe$
1114.5±2.0	$^{65}Cu(p,n)^{65}Zn$
1293.0±2.0	$^{58}Fe(n,\gamma)^{59}Fe$
1332.0±2.0	$^{60}Ni(n,n'\gamma)^{60}Ni$
1434.9±2.0	$^{52}Cr(n,n'\gamma)^{52}Cr$, $^{52}Cr(n,p)^{52}V$
1507.0±2.0	$^{55}Mn(n,n'\gamma)^{55}Mn$
1779.5±2.0	$^{28}Si(n,n'\gamma)^{28}Si$
1813.6±2.0	$^{56}Fe(n,p)^{56}Mn$
2115.0±2.0	$^{56}Fe(n,p)^{56}Mn$
2252.8±2.0	$^{55}Mn(n,n'\gamma)^{55}Mn$, $^{55}Mn(n,p)^{55}Cr$

correction for proton fluence). This ratio is close to the ratio of squares of distances $R_1^2/R_2^2 = 0.022$. Presence in a spectrum measured in an atmosphere, the γ-lines from (n,γ) reaction specifies presence of neutron radiation. Changing geometry of measurements, one can carry out the location of a source of neutron radiation.

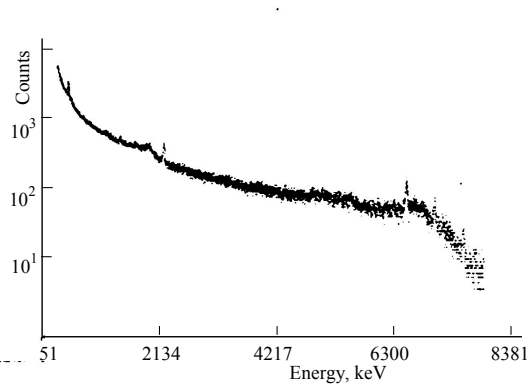

Fig.3. Gamma - spectrum measured outside of the accelerator building. Proton beam energy 10 MeV

Time spectra of γ - radiation have been investigated on accelerator U-12 at different energies (E_p=3.3; 6.3 and 10 MeV) in a hall where the accelerator is located, and behind its biological shield. The block diagram of measurements realizes a method of the synchronous detector described in work [2]. The signal from an analog output of a spectrometer inputs to the double-beam oscillograph C1-75 on which the other input was given a current pulse from the cooper target, where the proton beam was absorbed. NaI(TI)- spectrometer has been placed in a canyon of the accelerator on distance of 2 m from a target. Detector was shielding as mentioned above.

The analysis of oscillograms of signals from detector and a current pulse of the accelerator at energy of the proton beam 10 MeV shows, that during current pulse the spectrometer is overloaded. After 200 μs the spectrometer registers pack of pulses of delayed γ-radiation,

duration 7 ms. On the oscillogram measured at the proton beam energy 6 MeV delayed radiation has no pronounced time structure and the amplitude of pulses approximately in 2 times is less. At E_p=3 MeV delayed γ-radiation is not observed.

3. DETERMINATION OF THE PROTONS ENERGY

Measurement of spectra of the γ - radiation caused by induced activity, were carried out after a stop of the accelerator which has worked during 6 hours with the following parameters: the average current in a pulse - 1.2 mA, energy of the proton beam - 10 MeV, frequency 1 Hz. The beam was absorbed in the copper target (the copper foil set by full thickness of 340 g/cm^2) that provided full absorption of a beam. The mandrel of the target has been made of aluminum. In experiment it was used Ge(Li)- spectrometer with 125 см^3 crystal. Detector placed at 4 m from the target. During 24 hours after a stop of the accelerator a series from 6 measurements has been carried out. Energy of protons has been determined from the spectra of the induced activity by a technique stated in [3]. These measurements prove a possibility of restoration of energy of a primary beam shield analysis of γ-spectra of the induced activity.

4. CONCLUSION

The performed experimental research of pulse radiation accompanying work of the accelerator is shown:

1. There is a possibility of definition with a sufficient degree of reliability of primary parameters of the accelerator (energy and a current) by means of the registration behind biological protection neutron and γ-radiations.

2. There is a possibility of location of neutron source from ratios of intensity of γ-lines (from (n,γ) reactions) in the spectra measured in various points.

3. To define the type of accelerating particles by means of the registration secondary γ-radiation behind protection it is not obviously possible that γ-radiation from interaction of a primary beam with a material of a target is strongly suppressed by shield.

4. The probability of an estimation of energy of neutron radiation from the measured spectra of a γ-background is small, since the spectrum of neutrons has continuous character and is strongly deformed after passage of protection [4,5].

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ЭКСПЕРИМЕНТАЛЬНОЕ ИЗУЧЕНИЕ СПЕКТРАЛЬНЫХ И ВРЕМЕННЫХ ХАРАКТЕРИСТИК РАДИАЦИОННЫХ ПОЛЕЙ УСКОРИТЕЛЯ У-12

А.М. Егоров, В.Я. Мигаленя, В.И. Нагайченко, В.В. Сотников, В.А. Воронко, В.В. Жук

Работа посвящена экспериментальным исследованиям состава, временных и спектральных характеристик радиационного поля ускорителя У-12. Результаты исследований использованы при разработке мобильного комплекса для регистрации нейтронного и гамма-излучения вне ускорительного зала, а также для оценки эффективности радиационной защиты импульсных ускорителей.

ЕКСПЕРИМЕНТАЛЬНЕ ВИВЧЕННЯ СПЕКТРАЛЬНИХ І ЧАСОВИХ ХАРАКТЕРИСТИК РАДІЦІЙНИХ ПОЛІВ ПРИСКОРЮВАЧА У-12

О.М. Єгоров, В.Я. Мігаленя, В.І. Нагайченко, В.В. Сотников, В.А. Воронко, В.В. Жук

Робота присвячена експериментальним дослідженням складу, часових і спектральних характеристик радіаційного поля прискорювача У-12. Результати досліджень використані при розробці мобільного комплексу для реєстрації нейтронного і гама-випромінювання поза прискорювальним залом, а також для оцінки ефективності радіаційного захисту імпульсних прискорювачів.