TECHNOLOGICAL MEASURING CHANNEL FOR BREMSSTRAHLUNG MONITORING

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INTRODUCTION

For metrological support of radiation technological processes based on braking radiation (bremsstrahlung) of the electron accelerator necessary is continuous monitoring of next radiation parameters:

energy stream and energy of bremsstrahlung (B) ,

density of energy stream and transfer of energy of bremsstrahlung,

rate of absorbed doze and absorbed doze of bremsstrahlung,

in range of energy of braking photons 5..50MeV.

For realization of these requirements the technological measuring channel with primary sensor in the form of wide aperture thin-walled ionization chamber was developed by authors. The structure and metrological characteristics of the channel are described in this paper.

1. THE MEASURING CHANNEL STRUCTURE

The measuring channel of bremsstrahlung parameters includes primary measuring sensor – freeair ionization chamber IC-W and signal processing system.

The choice of geometrical characteristics of the IC-W is determined by conditions of bremsstrahlung generation in modern electron accelerators. Bremsstrahlung is produced by conversion of primary high power electron beam (>10kW). The primary electron beam of large intensity is scanned before it bring out to atmosphere, that determines magnification of geometric sizes of a field both primary and secondary radiation.

In conditions of radiation technological setups using bremsstrahlung the continuous not disturbing monitoring of its parameters is necessary. Taking into account reduced circumstances, as the primary measuring sensor the plane-parallel wide-aperture ionization chamber (IC) with a size of sensing area 220·555(sm^2) was developed. The chamber is made from aluminum and its effective thickness is 0.6 g/ sm^2.

For signal processing of IC-W sensor the measuring tract was created (Fig.1)

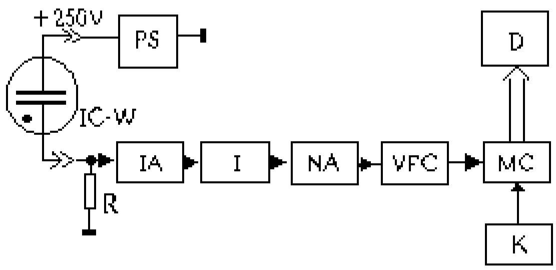

Fig. 1. The block diagram of the measuring channel for bremsstrahlung

The measuring channel is constructed on a modular principle, namely, for its operation are necessary only to apply voltage on IC (+250 V) and feed on the elements of the measuring tract (~220 V).

For a feed of the chamber, which works in a current condition, the power supply (PS) with stability not worse 10^{-5} is developed. The measuring resistor R is the load of the chamber IC-W. From the resistor R the signal, which is proportional to the value of energy stream through the chamber or to an average absorbed doze rate in the point of interaction of breamsstrahlung and irradiated object, arrives on input amplifier (IA) . The IA is an inverter with gain about 10 and it is implemented on OA type 544UD2. From the exit of the IA an amplified signal arrives on the active integrator (I). Its a time constant is τ=1.5s, that is much more than inversed frequencies of the accelerator and scanning of beam. Or else, the signal on the I exit is proportional to a current of IC-W, averaged by period τ. From the exit of the I the signal arrives on input of normalizing amplifier (NA). The NA is non inverting amplifier with high input resistance and gain 20, it is implemented on OA type 544UD2. From the exit of NA the signal goes to the input of the converter "voltage-to-frequency" (VFC). The converter is carried out on basis of the integrated circuit KP110PP1 (analog ICL8068). The nonlinearity of transformation does not exceed 0.01 % in a frequency band 0... 10kHz. The signal produced by VFC in digital forms arrives to the microcontroller unit (MC). The latter makes accounts of input pulses and it has a panel D for display of an information (matrix of LED indicators) and keyboard K for the set up one from the following operational modes of MC:

1 -definition and indication of an energy stream of bremsstrahlung;
2 -definition and indication of an energy value (absorbed doze) of bremsstrahlung;
3 -definition and indication of exposition time;

MC unit outputs control signal for alarm, when the setting exposition doze is reached. It is implemented on base of IC type 1816VE31 (analog Intel 8031). Executing program in volume 2kB is store in external ROM type K573RF5.

2.THE METHODS FOR MEASURING CHANNEL RESEARCH

2.1. For metrological research of measuring channel on base of IC-W sensor the method of computer simulation with software package ‘GEANT’ and with real geometric conditions of system (electron radiation-cooling by water converter of bremsstrahlung-air gap-collimator) was used (Fig.2). The dependence of the bremddtrahlung (B) energy stream on the output of collimator from electron energy was studied. Besides, the comparator methods using the standard ionization chamber IKV-6 from Standard 72-90 developed in VNIIM was used.

2.2. For measuring energy stream of B the next expression was used:

$$\Phi_E = k_1(E\gamma)\cdot n, \qquad (1)$$

where n is count rate of pulse in measuring tract(c^{-1});

k_1 is coefficient, depended from energy of γ-quantums of B and defined in result of calibration.

For measuring of B density of energy stream the next expression is used:

$$\varphi_E = \Phi_E / S, \qquad (2)$$

where S is area of input collimator placed in front of the IC-W sensor.

For measuring of energy of B the next expression is used:

$$W_E = k_1(E_\gamma)\sum_T n \cdot \tau , \qquad (3)$$

where T is exposition time of the IC-W in field of B.

The energy transfer of B is obtained from the formula

$$w_E = \frac{k_1(E_\gamma)}{S}\sum_T n \cdot \tau , \qquad (4)$$

The absorbed dose rate of B is obtained from the formula:

$$\dot{D}(E_\gamma) = S_{m,d}(E_\gamma) \cdot \frac{D_d}{\Delta t} \cdot \frac{n}{n_d} , \qquad (5)$$

where D_d is value of absorbed doze measured by the dosimeter's absorber for time exposition Δt,
$S_{m,d}(E_\gamma)$ is relationship between mass stopping power coefficients of absorber and dosimeter,
n_d is count rate of pulses in measuring channel during calibration .

The absorbed dose of B is obtained from the next expression:

$$D(E_\gamma) = S_{m,d}(E_\gamma) \cdot \frac{D_d}{\Delta t} \cdot \frac{\sum_T n \cdot \tau}{n_d} , \qquad (6)$$

3. METHOD OF MEASUREMENT

3.1. For metrological research of measuring channel the scheme on Fig.2 was used.

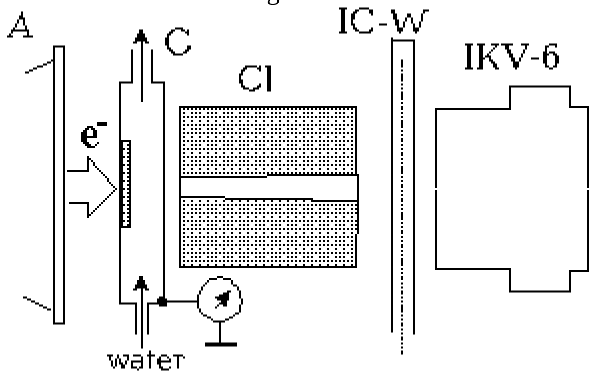

Fig.2. Scheme of measurement (not scanned electron beam): A-accelerator LINAC-10; C-converter; Cl-collimator (Pb, 200mm).

The construction of the converter C provides its a galvanic isolation to ground, that allows using the converter as the Faraday cup for additional monitoring of electrons a stream during measurements

Before the beginning of the measurements of the B parameters the following characteristics of the electron beam were measured. In this case the next parameters were monitored:

- Magnitude of a stream of electrons (by the built-in Faraday cup FC-2),
- Power spectrum (by the magnetic analyzer),
- Amplitude of a current in impulse (by built-in Rogovsky coil),
- Geometric performances (by mark on a irradiated glass).

For measurements in conditions of a not scanned electron beam the following parameters were monitored:

- the account rate of pulses n (s^{-1}) in a measuring tract IC-W,
- average current of the primary ionization chamber IKV-6 (by device B-7-40),
- average current of the converter (by device B3-27).

3.2. For metrological research of measuring channel in conditions of power scanned electron and brake radiation the scheme of measurement shown on Fig.3 was used.

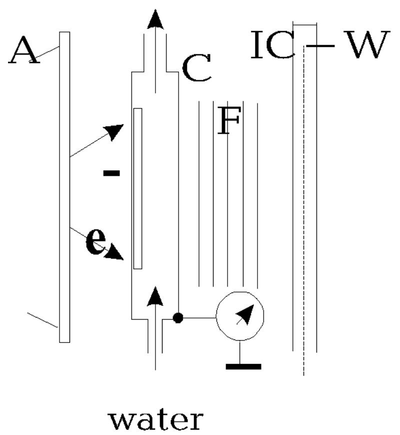

Fig.3. Scheme of measurement (scanned electron beam): A-accelerator LINAC-20; C-converter; F- filter (Al with thickness 45mm).

- the account rate of pulses n (s^{-1}) in a measuring tract IC-W, P_γ;
- electron beam pulse current ***I*** (by Rogovsky coil and converter current);
- electron energy (probable value) by electron beam length in scanning device;
- frequency of accelerator repetitions (by frequency-meter);
- geometrical size of brake radiation field (by mark on a glass placed after filter F).

4. RESULTS OF MEASUREMENTS

For realization of measurements in conditions of not scanned electron beam of the accelerator LINAC-10 the energy of electrons in a maximum of a spectrum was in range 10...16 MeV. The results of measurements are demonstrated in Fig.4.

For realization of measurements in conditions of the scanned electron beam (accelerator LINAC-20) the energy of electrons in a maximum of a spectrum was 21MeV. The geometrical size of the brake radiation field after filter F as~200x500mm^2. The results of measurements are shown in Fig.5.

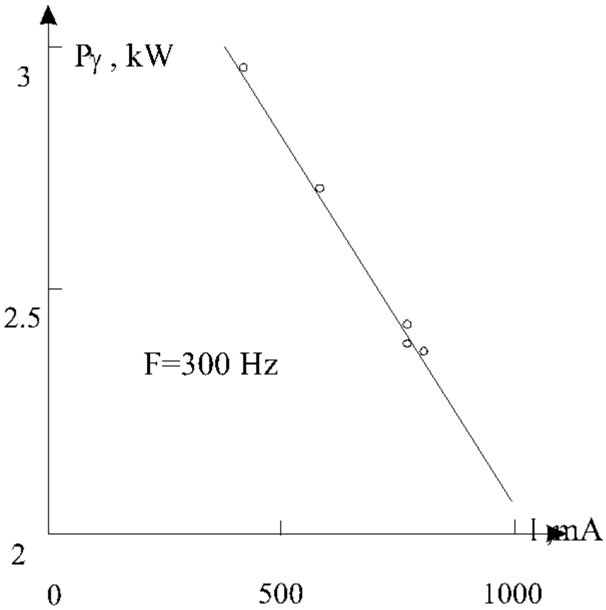

Fig.4. Bremstrahlung power dependence on pulse current amplitude

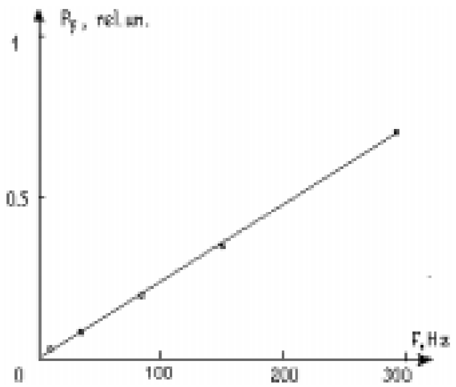

Fig.5. Bremstrahlung power dependence of beam pulse repetition rate

SUMMARY

1. Thus as result the technological measuring channel of was created and investigated for measuring of next physical parameters and values range of bremsstrahlung:

energy stream of bremsstrahlung (B), W $1.0{\cdot}10^{-1}\ldots1.0{\cdot}10^{4}$,

density of energy stream of B, $W{\cdot}m^{-2}$ $1.0{\cdot}10^{1}\ldots1.0{\cdot}10^{6}$,

energy transfer of B, $J{\cdot}m^{-2}$ $1.0{\cdot}10^{-2}\ldots1.0{\cdot}10^{9}$,

absorbed dose rate of B, $Gr{\cdot}s^{-1}$ $1.0{\cdot}10^{-3}\ldots1.0{\cdot}10^{10}$,

absorbed dose of B, Gr $1.0{\cdot}10^{3}\ldots1.0{\cdot}10^{11}$,

with next metrological characteristics:

main error in measurement of energy stream and density of energy stream, energy and energy transfer of B with confidence interval 0.95 - not more than 10%;

additional error connected with energy range of radiation - not more than 2%

additional error connected with measurement range - not more than 3%;

error in measurement of the absorbed dose rate and absorbed dose of bremsstrahlung – not more than 20%;

coefficient of conversion for measurement of energy stream, density of energy stream, energy and energy transfer of the B

$K1=2.42{\cdot}10^{-1}$ J/pulse.

2. The measuring channel on base of the ionization chamber IC-W has passed the metrological certification in VNIIM and can be used as operation instrument including the radiation technological setups with electron accelerators.

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