# STUDY OF OPERATING MODES OF STRAUS-R ACCELERATOR

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The description of a pulsed electron accelerator STRAUS-R (3.5 MeV, 60 kA, 60 ns) and results of its experimental research for two operation modes are given. In the mode of electron beam focusing the accelerator provides the focal spot of 3-4 mm diameter on a target and maximum exposure dose of 27 R at 1-m distance from the output window. In the irradiating mode the maximum dose achieves 36 R at 1-m distance from the target with inhomogeneity ≤ 30% within the area 0.36 $m^2$ (irradiation spot diameter is 0.6 m).

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STRAUS-R [1,2] (in Russian the abbreviation means High-Current Transforming Accelerator for Radiography) has enlarged a family of created before and successfully operating facilities such as STRAUS, STRAUS-2 and LIA-10M [3-5] that use a high-voltage pulse forming technology based on multicascade lines with distributed parameters. The accelerator generates single high-power X-ray pulses with the duration up to 50 ns in the mode of electron beam focusing on the target into small-size spot and it is destined for application in flash radiography. It is also applicable for research in the field of radiation physics and, with some modification, as an injector of a linear induction accelerator.

The main functional module of STRAUS-R is an accelerating system (overall dimensions 4.7×2.2×2.4 m) shown in Fig. 1. It consists of a Marx generator GIN-700, a high-voltage pulse forming system and a diode with an output vacuum chamber and focusing unit. Besides, the accelerator includes a high-voltage triggering system, automated system of monitoring and control, high-voltage charging unit, systems of vacuum pumping, gas filling, water and oil purifying.

Fig. 2 shows the sketch of the forming system with the diode and focusing unit. The high-voltage pulse forming system of STRAUS-R is designed basing on a water-insulated five-cascade double stepped forming line (DSFL) with 30-ns electric length of each cascade and total capacity of 93 nF. As well as in STRAUS-2 accelerator [3,4] the impedances of the DSFL sections were chosen to be the following: $Z_1$=0.9 Ω, $Z_2$=0.8 Ω, $Z_3$=1.9 Ω, $Z_4$=3.2 Ω and $Z_5$=18 Ω. The charging of the DSFL up to the voltage ≤ 650 kV within 0.8 μs is produced by an eight-cascade Marx generator with maximum energy store ~30 kJ (at $V_{max}$=100 kV) and shock capacity equal to 95 nF. Because of wave processes that arise at switching-off the line by 20 paralleled gas-filled trigatrons a seven-fold increase of voltage (up to ~4.5 MV in the idle mode) at the DSFL output is achieved as compared to its charging one.

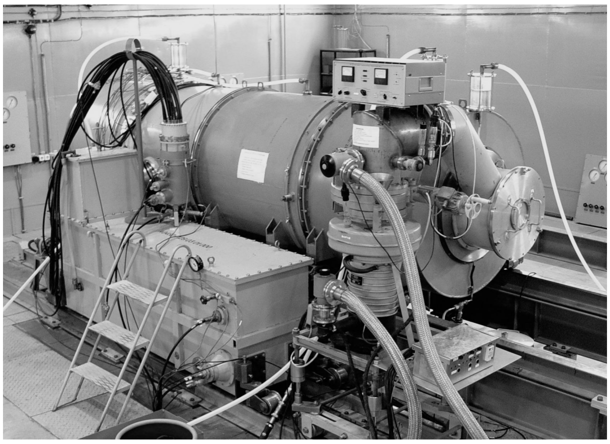

*Fig.1. View of the STRAUS-R accelerating system*

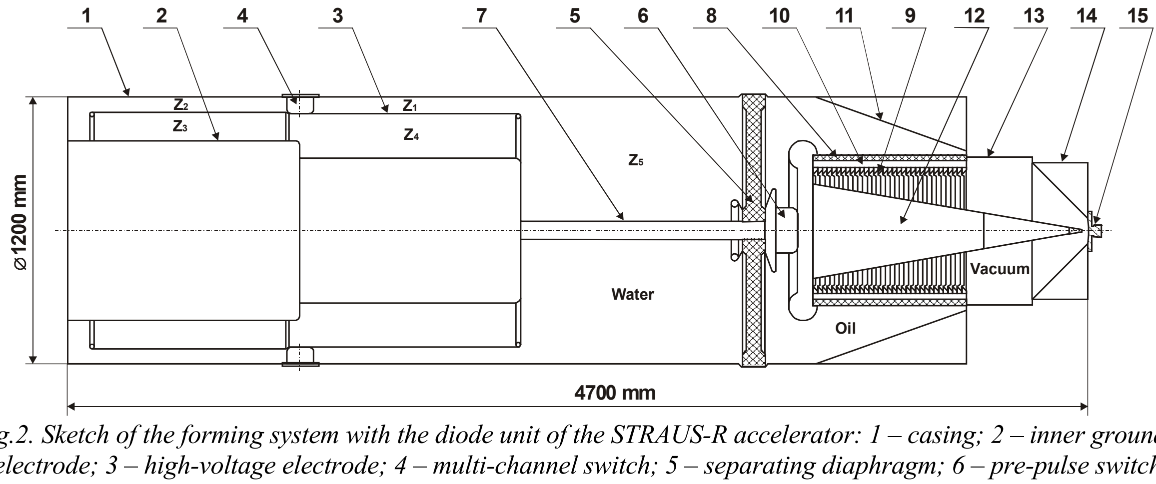


*Fig.2. Sketch of the forming system with the diode unit of the STRAUS-R accelerator: 1 – casing; 2 – inner grounded electrode; 3 – high-voltage electrode; 4 – multi-channel switch; 5 – separating diaphragm; 6 – pre-pulse switch; 7 - inner electrode of output line; 8 – dielectric tube; 9 – sectioned insulator; 10 – resistive load volume; 11 – conic*



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*electrode, 12 – cathode, 13 – output vacuum chamber, 14 – focusing unit, 15 – anode flange with a target unit*

The electron beam focusing occurs in a diode formed by converging conic transmission line with self-magnetic insulation whose inner cathode electrode is ended with a header of W-Ni-Fe alloy. The mounted at the anode flange tantalum disc combined with an aluminum collector of electrons serves as a target. A more detailed description of the STRAUS-R accelerator is given in [1].

During the experiments at the STRAUS-R accelerator more than 300 shots were produced to investigate its operation both in radiographic mode, with electron beam focusing on the target, and in irradiating one, without beam focusing. In the first case, a special focusing unit was mounted at the accelerator output (Fig.2). An anode-cathode gap in the diode was varied from 10 to 25 mm with the set of conic cathode endings, made of W-Ni-Fe alloy, with an annular or flat face edge of diameter from 5 to 15 mm. A thickness of a tantalum target is also changed from 0.3 to 1 mm. In the second case, a configuration of the accelerator diode was analogous to applied one in the STRAUS-2 facility [4,6]. As a cathode a solid graphite cylinder ∅ 35 mm with two coaxial annular edges, faced to anode, was used. A tantalum target of 150-mm diameter and 0.5-mm thickness was attached to a removable aluminum anode flange that served as a collector of electrons passed through the target. The accelerating gap was varied within 40…70 mm by moving the cathode along the diode axis.

Depending on a delay between on-times of the pre-pulse and multichannel switches of DSFL the accelerator allows realization of the beam current pulses of various shape and duration (Fig.3). To achieve the highest dose parameters at the facility output a charging voltage of the DSFL and resistivity of the electrolytic load of the diode unit were chosen near to maximum permissible (650 kV and 1500 Ohm·cm, respectively), and the pre-pulse switch was tuned in such a way as to provide a maximum duration of a formed pulse. Further optimization consisted in matching a required impedance of the diode by varying the accelerating gap.

In the radiographic mode (with beam focusing), maximum output dose parameters together with required quality of beam focusing were achieved with a cathode having an annular face edge with outer/inner diameters of 10/6 mm, 15-mm anode-cathode gap and 0.3-mm thickness of tantalum target.

It entirely corresponds to the data obtained before on the STRAUS-2 accelerator [6] in spite of the fact that these facilities are different first and foremost in the duration of formed pulses and power parameters. As illustrations, a photograph of the target after single shot of STRAUS-R, an X-ray image of the focus spot and a distribution of radiation intensity over the target are shown in Fig.4.

In the irradiating mode (without beam focusing), a maximum X-ray dose (36 R at 1-m distance from the target) was realized at the accelerating gap of 60 mm in the diode. The main characteristics of the STRAUS-R and the oscillograms of its output pulses for two investigated operation modes of the accelerator tuned to achieve the maximum dose parameters are presented in Table and in Fig.5, respectively.

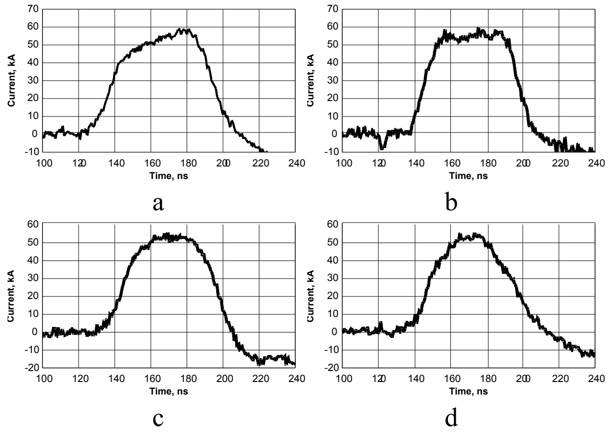


*Fig.3. Diode current pulses of STRAUS-R accelerator*

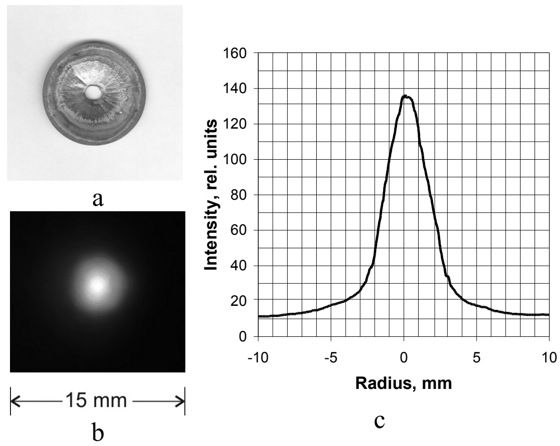


*Fig.4. Photograph of a target (a), X-ray image of a focus spot (b) and distribution of radiation intensity (c) over the accelerator target*

*Main parameters of the STRAUS-R accelerator for two operating modes*

| Parameter | Radiographic mode | Irradiating mode |
|---|---|---|
| Accelerating voltage, MV | 3.3 | 3.7 |
| Peak beam current, kA | 60 | 50 |
| Current pulse width at half-maximum, ns | 60 | |
| X-ray pulse width at half-maximum, ns | 50 | |
| Focus spot diameter on the target, mm | ≤ 4 | — |
| Maximum X-ray dose, R: at the output flange | $2.5 \cdot 10^4$ | $1.4 \cdot 10^4$ |
| at 1-m distance from the target | 27 | 36 |
| Irradiation spot diameter (with inhomogeneity ≤ 30%), cm: at the output flange | 4 (4 cm from the target) | 6 (1 cm from the target) |
| at 1-m distance from the target | 65 | 60 |

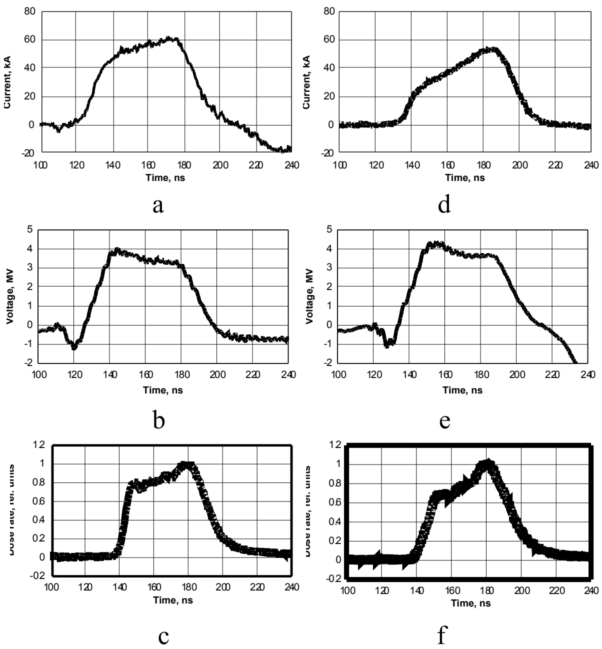


*Fig.5. Pulses of the beam current (a, d), diode input voltage (b, e) and X-rays (c, f) of the STRAUS-R accelerator in radiographic (a-c) and irradiating (d-f) modes*

In both cases the output pulses of the accelerator are similar by time-amplitude characteristics, but the dose parameters of generated X-ray radiation are different. In the radiographic mode, when the beam focusing is used, the X-ray dose nearby the target unit of the accelerator is appreciably higher while the dose level at 1-m distance from the target is some lower than in the irradiating mode. On the one hand, this is caused by much higher concentration of beam energy on the target and on the other - by some deterioration of angular characteristics of electron beam in the diode as compared to the mode of unfocused beam.

At present experimental investigation of the STRAUS-R accelerator is completed for the most part. The obtained results showed possibility of its application as a “point” X-ray source in flash radiography as well as an irradiating facility for research in the filed of radiation physics.

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## ИССЛЕДОВАНИЕ РЕЖИМОВ РАБОТЫ УСКОРИТЕЛЯ СТРАУС-Р


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Приведены описание и результаты исследований импульсного электронного ускорителя СТРАУС-Р (3,5 МэВ, 60 кА, 60 нс) в двух режимах его работы. В режиме фокусировки электронного пучка ускоритель обеспечивает получение на мишени фокусного пятна диаметром 3…4 мм при максимальной дозе тормозного излучения 27 Р на расстоянии 1 м от выходного фланца. В облучательном режиме максимальная доза тормозного излучения на расстоянии 1 м от мишени по оси ускорителя достигает 36 Р с неоднородностью ≤ 30% на площади 0,36 м$^2$ (диаметр пятна облучения 0,6 м).


## ДОСЛІДЖЕННЯ РЕЖИМІВ РОБОТИ ПРИСКОРЮВАЧА СТРАУС-Р

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Наведено опис і результати досліджень імпульсного електронного прискорювача СТРАУС-Р (3,5 МеВ, 60 кА, 60 нс) у двох режимах його роботи. У режимі фокусування електронного пучка прискорювач забезпечує одержання на мішені фокусної плями діаметром 3...4 мм при максимальній дозі гальмівного випромінювання 27 Р на відстані 1 м від вихідного фланця. При опроміненні максимальна доза гальмового випромінювання на відстані 1 м від мішені по осі прискорювача досягає 36 Р с неоднорідністю ≤ 30% на площі 0,36 $м^2$ (діаметр плями опромінення 0,6 м).



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