APPLICATION OF LINEAR ELECTRON ACCELERATORS TO INDUSTRY AND MEDICINE

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Introduction

The united series of linear electron accelerators applied to industry and medicine has been developed at D.V.Efremov Institute. The operation experience of the accelerators having been earlier constructed, status and trends for their development have been taken into account.

The main purposes of this united series development are the following:

I. Beam stability rise and improved beam reproducibility, including linacs-models designed for the frequent variation of operation modes.

2. Rise of average beam power and electrons energy in linacs intended for non-destructive testing, activation analysis and isotopes production.

3. Increased reliability.

4. Unification of linacs components.

5. Control automatization.

6. Mass and overall-dimensions reduction.

Design, construction and testing of linacs prototypes have shown that the abovesaid purposes are attained.

Klystron for 2450 MHz with the output power 5 MW has been developed specially for linacs united series. It is designed for operation at anode voltage not more than 55 kV, as low anode voltage facilitates overall dimensions and mass reduction of klystron supply sources. Use of permanent magnets periodic system for the beam focusing in this klystron permits to exclude the electromagnet with the stable supply source. For klystron excitation, compact pilot generator with the output power 100 W and frequency stability 10^{-5} has been developed.

The automatic control system on mini-computer base, which not only facilitates but also impoves the accelerator performances and widens the rendered services is used in these accelerators.

In comparison with earlier models, the equipment overall dimensions and mass are significantly (1.5-2 times) reduced.

Accelerators for non-destructive testing

Three linacs models for non-destructive testing cover the wide range of X-ray energies and dose rates /1/. It permits to perform the non-destructive testing of 40-600 mm thick steel articles with high sensitivity at high production rate. The accelerators main performances are given in Table I.

Table I

Performances	Model		
	UELV-5-ID-15	UELV-10--2D-40	UELV-15-2D-80
Ultimate X-ray dose rate, Gy/min	13.5	41	86.5
Ultimate energy of the accelerated electrons, MeV	6	9	13
Irradiation field diameter at 1 m distance from the target, mm	535	350	210
Steel thickness, irradiated for 10 min, mm	300	375	435
Steel thicknesses range, controlled with the accuracy not less than 1%, mm	40-400	50-500	75-600

The accelerators have the diode electron gun with the injection voltage 50 KV. As an accelerating structure, the diaphragmatic waveguide with $a/\lambda = 0.074$ is used. The decelerating target with the service life not less than 1000 hours is installed at the abovesaid waveguide exit. The irradiator is directed onto the controlled object using the laser beam. The irradiator rotation angle is from +180° to -135° in horizontal plane and from +45° to -90° in the vertical.

Medical accelerators

There are two models of medical accelerators /2/, their main performances are given in Table 2.

In medical accelerators 3-electrode guns with the grid control and injection voltage 20 kV are used. The standing wave structure with on-axis coupling cavities at $\pi/2$ oscillation mode is used as an accelerating one. Shunt impedance is $Z = 75 M\Omega/m$, coupling factor $K = 0.02$.

Table 2

Performances	Model	
	LUER-20M	LUER-40M
X-ray		
- electron energy, MeV	6, 18	8, 18
- maximum dose rate, Gy/min	3	1.5 (for 8 MeV) 3 (for 18 MeV)
- irradiation field sizes at 1 m- distance from the target, cm x cm	2x2-40x40	2x2-40x40
- non-uniform dose distribution in the irradiation field (from 5x5 fields, to 30x30 cm), 5%	± 3	± 3
Electrons:		
- electrons energy, MeV	5-20	5-40
-maximum dose rate, Gy/min	5	5
- maximum irradiation field sizes in isocenter plane, cm x cm	26x26	26x26
- dose non-uniform distribution in the irradiation field, 5%	±5	±5
Gantry rotation angle, degrees	360	360
Gantry rotation speed, rev/min	0.1-1	0.1-1
Target-to-axis distance, cm	100±0.2	100±0.2
Diaphragm system rotation angle, degrees	±90	±90
Isocentre height, cm	128	135

The beam double acceleration in a single accelerating structure is used in LUER-40M. The standing wave accelerating structure permits to accelerate electrons in both directions. After the first passage the beam is 180° bent by the achromatic isochronous magnetic system. The device, permitting to obtain the electron beams with the required parameters for two X-ray radiation modes of operation: 6 and 18 MeV is provided in an accelerating structure of LUER-20M.

To direct the electron beam into the radiation head which is the radiation fields formation system-the double achromatic magnet bending system with the total angle - 130° is used. Radiation head provides formation of axially-asymmetric irradiation fields and also of irradiation fields with a certain isodose inclination.

Accelerators for radiation technology, activation analysis and isotopes production

There are three accelerator models, their performances are given in Table 3.

Table 3

Performances	Model		
	UELV-10-15	UELV-15-10	UELV-30-20
Ultimate energy, MeV	8	15	30
Energy control range, MeV	4-12	6-19	6-38
Ultimate average power, kW	16.5	9.2	18.4
X-ray dose rate under nominal mode of operation, Gy/min	370	580	1430
Neutron output under nominal mode of operation, neutrons/s	$1.5 \cdot 10^{12}$	$9.3 \cdot 10^{12}$	$6 \cdot 10^{13}$

UELV-10-15-accelerator is firstly intended for the radiation technology, for such energy-intensive processes as polyethelene and other similar materials radiation modification, medical instruments sterilization, rubber vulcanization and so on. This accelerator also as UELV-15-10 may be used for X-ray radiation production, for example, for radiation treatment of materials with higher density.

Activation analysis, carried out using these accelerators, primarily intended for the materials element analysis using photonuclear methods, permits to make the detailed analysis of polymetallic ores at metallurgical plants.

The accelerators may have a converter for the neutrons production. Combination of photonuclear methods and neutron-activation methods will permit to analyze practically all the elements of Mendeleev table.

Accelerator UELV-30-20 due to its parameters versatality may be used both for fundamental and applied researches in physics, chemistry and material science.

Accelerators UELV-15-10 and especially UELV-30-20 may be used also for short-life isotopes production, particularly ^{123}J necessary for medical diagnostics.

Conclusion

Carried out designing, construction and testing of prototype accelerators have shown that the aims in view are attained. Beam stability and safety are increased, beam characteristics reproducibility is improved, accelerators components are unified, automatic control is realized and mass and overall dimensions are reduced.

References

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2. Budtov A.A. et all. NIIEFA linear accelerators for beam therapy. Voprosy atomnoi nauki i tekhniki. Series: Electrophyzicheskaya apparatura. 1987, vyp.23, p.512.