THE UNIFIED SERIES LINEAR ELECTRON ACCELERATORS DEVELOPMENT RESULTS

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Abstract. New linear electron accelerators for industry and medicine have been developed on the basis of low-voltage (50-55 kV) klystron with pulse power up to 5 MW. Beam therapy accelerators use biperiodic accelerating structure with on-axis coupling cavities and special unit for significant variation of accelerated electrons energy. Linear electron accelerators for non-destructive testing employ high-dispersion diaphragmed waveguide accelerating structures with the average accelerating rate more than 11 MeV/m. Linear electron accelerators for radiation processing provide an electron beam with power more than 15 kW to be produced in a single-section accelerating device due to employed klystron of high average power.

Nowadays new models of linear resonance electron accelerators (LUE) to be applied to industry and medicine have been developed and are manufactured in scientific-industrial amalgamation "Electrofizika" (D.V.Efremov Institute). They may be united into three groups of machines according to the fields of application:

- LUE for beam therapy[1];
- LUE for non-destructive testing of articles and materials and also for radeoscopic visual inspection of cargos in containers and car-bodies[2];
- LUE for radiation processing, activation analysis and production of short-lived isotopes (medical diagnostics) [3].

The objectives for new LUE-models developing were the following: higher accelerated electron beam parameters stability, improved beam parameters reproducibility while changing the operation mode, possibility for programmed change of ionizing radiation parameters during treatment session. To resolve these problems, klystron amplifier should be used as RF-power source [4] instead of magnetron generator. Independent stabilized klystron exciter would permit to rise significantly RF-frequency stability, being the main factor upon which the accelerated electrons energy stability depends. Previously manufactured power klystron amplifiers required three times as high pulse anode voltages as magnetrons for their supply what significantly enlarged pulse modulators mass and dimensions. To overcome this drawback, klystrons with low anode voltage comparable with that of magnetrons were developed.

LUE unified series uses klystron amplifiers with pulse power 5 MW operating at anode voltages less than 50-55 kV. They offer high gain coefficient approximately 50 dB and efficiency about 40%. Their specific feature is packeted resonance block with permanent focusing magnet system what made unnecessary focusing electromagnet with its power supplies. It should be noted that anode voltage reduction in some cases makes significantly more simpler measures on maintenance personnel protection against X-ray radiation appearing in klystron. There are two modifications of such low-voltage klystrons: for the average power 5 kW and 25 kW.

Developed LUE-series for beam therapy consists of two models: first-basic for accelerated electrons energy up to 20 MeV and second - for energy up to 40 MeV. In the latter version electrons energy is doubled due to their recirculation after being 180°-bent by achromatic isochronous magnet system.

LUER-20M for 20 MeV meets all present-day radiation therapy requirements. It provides fields with required parameters operating with electrons of six different energies and X-ray radiation in the mode with 6 and 18 MeV. This accelerator may be used both for multi-port irradiation and that with 360°-rotation.

For energy significant variation under the photon irradiation mode the device for energy control in a standing wave biperiodical accelerating structure with on-axis coupling cavities was suggested and realized. It permits to change the phase of RF-field interacting with the electron beam at the accelerating structure exit. Keeping the beam dynamics practically unchanged in its initial part, the electrons may be additionally accelerated or retarded afteir their passage through this device. Typical energy and spectral characteristics are given on Fig.1.

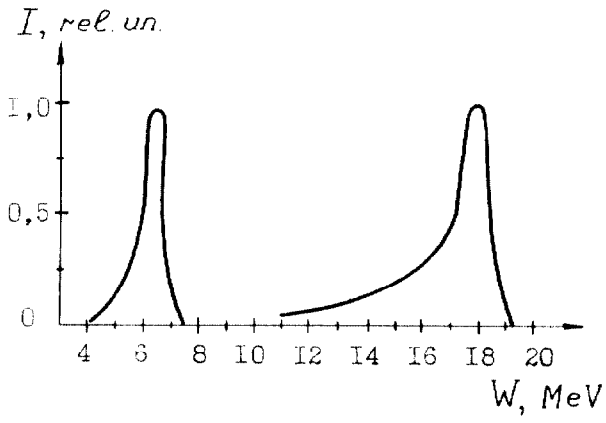

Fig.1. Spectral and energy characteristics of LUER-20M-accelerator at energies 6 and 18 MeV

At given energy spectra 70-75% of electrons pass through the "slalom" bending system. In LUER-20M accelerating structure is mounted at 40° to the rotation axis. The beam is 130° bent by the magnet. At both abovesaid energies the focus spot on a target isn't more than 2 mm. The specific feature of these linear accelerators developed in "Electrofizika" is possibility for programmed rotational and multi-port irradiation during the treatment session (minicomputer based automized irradiation system is used).

LUE-series for non-destructive control consists of three models covering the wide range of X-ray rated energies from 6 to 16 MeV. Due to powerful RF-source used in these accelerators, rather high X-ray dose rate - 15 and 30 Gy/min at 1 m from the target is attained. High intensities make possible significant exposure time reduction at radiographic control of large thickness articles. In connection with use of new radiation control methods, such as real time introscopy and computerized tomography, the special attention was paid to rising of the dose rate stability from pulse to pulse and long-term stability. Higher stability is achieved both due to klystron employed instead of magnetron and high-dispersion waveguide accelerating structures with high acceleration rate, unfortunately being less frequency-dependent than resonator structures.

The third group of accelerators is designed for radiation processing. It comprises single-section accelerators for the rated energy 8 and 15 MeV with the accelerated electrons power 15 and 8 kW, respectively. 8 MeV-accelerators are applied for medical articles and preparations sterilization and food irradiation. Also they successfully may be used for -activation element analysis of practically all the elements of Mendeleev table. Effective sources of ionizing radiation for and neutron-activation analysis are 15 MeV single-section accelerators and double-section accelerators for the rated energy 30 MeV. Construction of double-section accelerator for higher average power (up to 16 kW) becomes possible due to use of two klystron accelerators of average power 25 kW. Klystrons application, contributing to higher operation stability and better energy spectrum permits to reduce losses at beams transportation in output devices. Accelerator for high energies at high beam power may be used to produce short-lived isotope - I^{123} - widely applied in medicine for diagnostics.

Powerful LUE similar to the other accelerators of unified series, are adapted to be used in computer-based automized radiation complexes.

References

1. A.A.Budtov, Yu.P.Vakhrushin, Yu.Yu.Kirillin et all. "NIIEFA linear accelerators for beam therapy". In collection: Voprosy atomnoi nauki i tekhniki, series: Electrofizicheskaya apparaturs, N 23, 1987, p.5-12.
2. Yu.P.Vakhrushin, A.P.Klinov, V.M.Nikolaev et all. "New series of linear electron accelerators for radiation defectroscopy". Ibiden, p.3-5.
3. Yu.P.Vakhrushin, V.I.Muntyan, V.M.Nikolaev et all. "New linear accelerators for radiation processes, activation analysis and isotopes production". Theses of V All-union meeting on applied charged particles accelerators. October 22-24, 1985, Leningrad, p.7.
4. V.M.Bystrov, S.V.Galaktionov, V.E.Demin, I.A.Freidovich et all. "Amplifyind klystron for resonant electron accelerators". In collection: Voprosy atomnoi nauki i tekhniki. Series: Tekhnika fizicheskogo experimenta, N 4/35, 1987, p.6-7.
5. A.P.Klinov, N.D.Malitsky, Yu.P.Severgin, V.A.Titov. "Bending focusing magnets for therapeutic linear electron accelerators". Theses of VI All-union meeting on applied charged particles accelerators". October 11-13, 1988, Leningrad, p.250.