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# PROSPECTS OF CREATING A MODERN RESONANCE ELECTRON ACCELERATOR

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*Abstract*

The paper reports a brief description of a linear electron accelerator LU-10-20 and the necessity for its upgrading. A review of existing native and foreign RF power sources, meeting the assigned requirements for the RF power supply system of the upgraded accelerator, is presented. A design of the travelling wave accelerating structure based on disk-loaded waveguide is presented.

Preliminary electro-dynamic calculations of the accelerating section fed by the selected RF power source are presented as a paper result.

## INTRODUCTION

A linear resonance electron accelerator LU-10-20 [1] aimed at carrying out radiation processing of materials and researching radiation processes has been functioning in RFNC VNIIEF since 1994. The average energy of accelerated electrons is up to 10 MeV, the average electron beam power – up to 12 kW. This accelerator has demonstrated that it is highly useful for performing radiation researches and tests.

Currently the major part of accelerator systems, such as RF power supply system and accelerating structure, have lost its original characteristics during a long-term performance and possess an obsolete material and component base. That is why the design and development of a modern accelerator complex with the similar output parameters of electron beam, high reliability and large period of undisturbed operation is highly promising. Such a linear accelerator should replace LU-10-20 in future.

## RF POWER SOURCES

The base for development of a modern accelerator complex based on linear resonance electron accelerator is a RF power supply system. Magnetrons and klystrons are mostly spread as RF power sources. They possess by rather a high efficiency, high reliability and a large lifetime.

Magnetrons and klystrons should correspond to the following requirements to supply the required electron beam parameters: the output average power – about 20 kW, output pulse power – approximately 10 MW, operating frequency – up to 3 GHz.

These requirements are met by RF power sources, meant for employment in linear electron accelerators, produced by a number of native and foreign manufacturers of microwave-devices. Table 1 reports parameters of some RF power sources of the given manufacturers.

Table 1: Magnetrons and Klystrons Parameters

| Name | $f_{oper.}$, MHz | $P_{pulse.}$, MW | $P_{aver.}$, kW | Manufacturer |
|---|---|---|---|---|
| Magnetron MI-328 | 1818 | 6,5 | 22 | «Toriy» (Moscow) |
| Klystron KIU-15 | 1818 | 20 | 18 | «Istok» (Fryazino) |
| Magnetron MI-435 | 1886 | 10 | 22 | «Toriy» (Moscow) |
| Magnetron MI-470 | 1886 | 10 | 30;50 | «Toriy» (Moscow) |
| Klystron KIU-53 | 2797 | 12 | 18 | «Kontakt» (Saratov) |
| Klystron KIU-147A | 2856 | 6 | 25 | «Toriy» (Moscow) |
| Klystron VKS-8262F | 2856 | 5 | 36 | CPI, USA |
| Klystron TH 2128 A | 2856 | 45 | 20 | Thales, France |
| Klystron TH 2128 E | 2856 | 30 | 24 | Thales, France |
| Klystron TH 2100 C | 2998 | 45 | 20 | Thales, France |

All above-mentioned RF power sources have output power pulse duration from 4 up to 16 µs.

To modernize LU-10-20 linear accelerator most suitable are magnetrons MI-328, MI-435 and MI-470 produced by «Toriy», as well as klystron KIU-15 manufactured by «Istok». These microwave-devices allow provision of required average electron beam power not less than 10 kW and average accelerated electron energy up to 10 MeV. Additional factor in favor of selection of Russian manufacturer of microwave-devices is more profitable delivery conditions, as compared to the foreign analogs.

## TYPE OF ACCELERATING STRUCTURE

The accelerating structure for linear resonance electron accelerator, meant to replace LU-10-20, should provide an output average power of an electron beam more than 10 kW with average energy of electrons up to 10 MeV.

Linear resonance electron accelerators have two types of accelerating structures: standing wave and travelling wave structures. Standing wave structures have a high efficiency of the use RF power from microwave-device for electron acceleration and can provide forming and further acceleration of the electron bunches without use of a focusing solenoid. Travelling wave structures allow possibility to vary the energy of accelerated electrons within some limits by a change of electron beam current. These structures possess less strict requirements for

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accuracy of manufacturing the accelerating structure elements so they simplifies and reduces the price of their development [2].

As an accelerating structure there is selected a travelling wave structure based on disk-loaded waveguide with a variable geometry. Phase shift per cell in the disk-loaded waveguide is 2π/3. This structure is similar to LU-10-20 current section. The main reasons in favor of such a structure selection is a presence of experience for development and maintenance of linear electron accelerators with travelling wave structures, simplicity and cheapness of manufacture, availability of aperture for electron beam of larger diameter and a more simple RF power supply system as compared to standing wave structures.

## PRELIMINARY CALCULATIONS OF ACCELERATING SECTION

For preliminary electro-dynamic calculations the magnetrons MI-328 and MI-470 manufactured by «Toriy» are selected as a RF power source. MI-328 magnetron has an operating frequency 1818 MHz, a output peak pulse power about 6.5 MW and pulse duration 3.8 µs. Output characteristics of magnetron MI-470: output peak power about 10 MW, pulse width – 10 µs, operating frequency – 1886 MHz.

Basing on MI-328 magnetron parameters, preliminary calculations are performed in the program DINEX [3]. Travelling wave accelerating structure has variable geometry and phase shift per cell 2π/3. Operating frequency is 1818.7 GHz. The accelerating structure length is 2.1 m. The electron beam with energy 50 keV and pulse beam current 0.35 A is injected into the given accelerating section.

Calculations have shown that the linear electron accelerator, involving this accelerating structure with RF power from the selected microwave oscillator, allows obtaining electron beam average power 10.4 kW at current pulse repetition rate 1000 Hz and average beam energy about 8.3 MeV.

The output energy spectrum and the phase-energy portrait of electron beam are given in Figs. 1 and 2.

A similar calculation is performed for the accelerating structure, based on the magnetron MI-470 parameters. Operating frequency is 1886 GHz. The accelerating structure length is 2.1 m. The electron beam is injected with energy of electrons 50 keV and pulse beam current 0.55 A.

As a result of calculations there is obtained an average electron beam power 14.3 kW at the current pulse repetition rate 300 Hz, average beam power is about 8.9 MeV.

The output energy spectrum and the phase-energy portrait of electron for the accelerating structure based on magnetron MI-470 are given in Figs. 3 and 4.

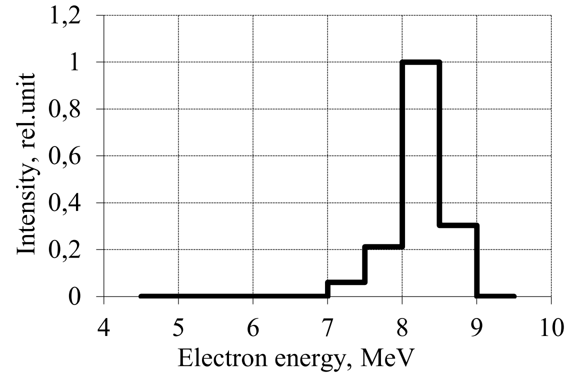


Figure 1: Output energy spectrum of electron beam.

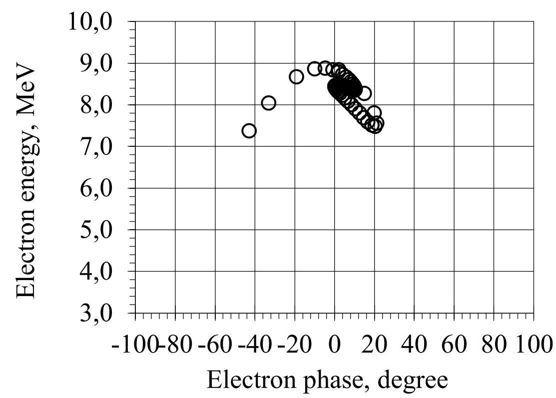


Figure 2: Output phase-energy portrait of electron beam.

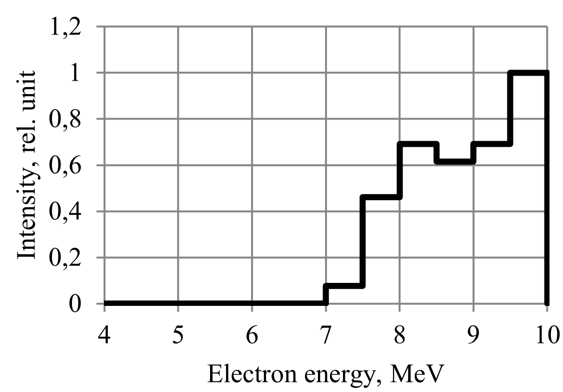


Figure 3: Output electron beam energy spectrum.

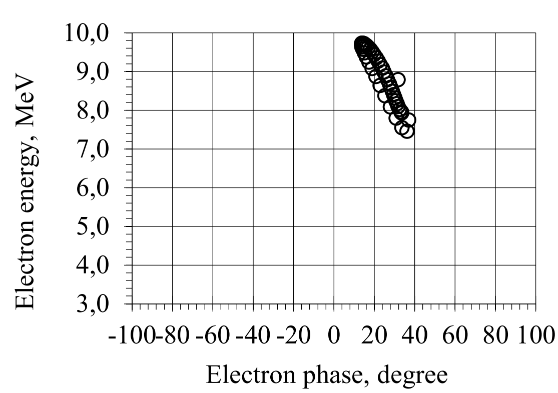


Figure 4: Output phase-energy portrait of electron beam.

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## CONCLUSION

Existing native and foreign microwave oscillators have been reviewed. They meet assigned requirements for the RF power supply system of the advanced accelerator.

Electrodynamics calculations of the accelerating sections, based on parameters of magnetrons MI-328 and MI-470, have been performed. The calculation results have shown that electron beam output characteristics for the given sections quite meet the assigned requirements.

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