COMPACT ELECTRON LINAC LU-7-2 FOR RADIOGRAPHY OF LARGE-SCALE OBJECTS

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At RFNC-VNIIEF there was started up a compact LU-7-2 linear electron accelerator designed for industrial application in the field of radiography of objects with a large mass thickness as well as for development of radiation technologies.
For accelerator microwave power supply there was used a magnetron operating on a wavelength of 10.7 cm with a pulse power of 2.5 MW. Accelerating structure was created on the basis of a circular disc-loaded waveguide with varying geometry of accelerating cells, operating on a traveling wave of 2π/3 mode. Electrons are injected by a diode type 50 kV electron gun.
The achieved parameters allow to use the accelerator for radiography of objects with a large mass thickness.

PACS number: 29.17.+w

1 INTRODUCTION

In radiography field there exists a number of problems for whose solving most preferably is to use rather mobile and at the same time powerful sources of hard quanta- emission. For example:

- flaw detection of large-scale and stationary facilities;
- flaw detection at emergency, when the time factor acquires a determinative meaning (flaw detection in the real time mode);
- flaw detection in the areas located far from the sources of power supply;
- radiography of objects at customs to increase a transmission capacity and control quality of shipped loads.

Linear electron accelerators are rather effective for solution of these problems as they stand out among other sources of ionizing radiation, first of all in high energy and power of generated radiation. The use of portative linear accelerators also can turn out an economically beneficial solution for many productions whose technological cycle does not require constant application of such type devices.

RFNC-VNIIEF has developed and put into service a compact linear electron accelerator LU-7-2 designed for industrial use in the field of radiography of objects with a large mass thickness [1] and for development of radiation technologies.

2 ACCELERATOR DESIGN

As a source of microwave power a MI-456A magnetron [2] for accelerator was used. Its main characteristics are:

- pulsed power.................................... 2.5 MW;
- off-duty factor.................................. (600-2000);
- pulse duration.................................. (3.8-10) μs;
- operating frequency range............... (2797±5) MHz;
- standing-wave factor of load........... no more than 1.5;
- magnetron mass.............................. 7.1 kg.

Accelerator accelerating structure is designed on the basis of a circular disc-loaded waveguide (CDLW) operating on the 2π/3 mode on traveling wave.

A flow diagram of LU-7-2 accelerator is given in Fig. 1. The magnetron and electron gun were supplied from one 50 kV modulator. To isolate the magnetron from the accelerator a three-port circulator was applied. Microwave power was input into the accelerating structure through the input mode converter (MC). The residue of the unconsumed microwave power was removed through the output MC into the absorbing load with water cooling.

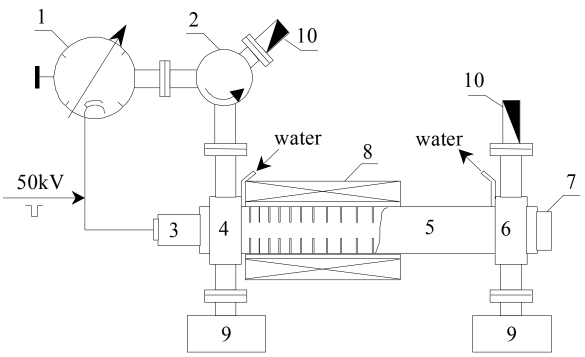

Fig. 1. Accelerator flow diagram:
1 - magnetron; 2 - circulator; 3 - electron gun; 4 - input MC; 5 - accelerating structure; 6 - output MC; 7 - output device; 8 - solenoid; 9 - vacuum magnetic-discharge pump; 10 - absorbing load.

Magnetic focusing of the electron beam was performed by a constant longitudinal magnetic field formed by the solenoid.

To inject electrons into the accelerator, one used a 50 kV electron gun of diode type with a flat impregnated cathode of 6 mm diameter.

During operation a magnetic-discharge pump of NORD-100 type supported vacuum in the accelerator at the level of $1.1 \cdot 10^{-4}$ Pa.

The accelerated electron beam was output in the atmosphere through a two-layer titanium-aluminium foil of 40mcm thickness.

Thermostabilization (with accuracy of ±0.5ºC) of accelerating section was provided with the aid of water cooling circuit.

3 CALCULATION AND EXPERIMENTAL PARAMETERS OF ACCELERATOR

Calculation of parameters of accelerating structure and electrons dynamics was carried out with the aid of DINEX program developed at VNIIEF [1]. The program algorithm was realized through the use of reference data [3], experimental results obtained at development of previous accelerators [4] and numerical methods.

To reach the required output electron power, there was selected a CDLW variable geometry with a change of load factor over the whole structure length.

As a result of calculations performed we have obtained expected parameters of accelerated electron beam at accelerator's operating frequency of 2797 MHz and average microwave supply power of 4 kW.

- accelerated electron energies...................... (6-7) MeV;
- average power of electron beam................. 2 kW.

Thus, the weight of CDLW with input and output MC, electron gun and output device is about 70 kg at 1.7 m accelerator's length.

Physics start-up and further testing of the accelerator in different operation modes were carried out on a specially produced stand. To provide magnetic focusing, at initial stages of the work a laboratory solenoid providing a magnetic field strength on the axis up to 0.2 T was used. This allowed us to determine experimentally optimal solenoid parameters that would be used in the transportable accelerator variant.

The accelerator was tested at an average magnetron microwave power of 2.2 kW, 4 ms pulse duration and 250 Hz pulse repetition rate. A pulsed value of injection voltage supplied onto the electron gun was 50 keV.

The optimal solenoid magnetic field strength on the accelerator's axis was in the range from 0.03 to 0.05 T. The field strength was selected by the average current and the accelerated electron beam profile that was taken with the aid of radiation monitoring film placed at a distance of 20 mm from the outlet foil (Fig. 2). Equidensities and their values in the figure show the relative distribution of the dose absorbed over the beam cross-section.

The average accelerated electron current was measured with the help of the Faraday cylinder. Electron energies were measured by the method of electron beam absorption when the beam passed through a set of aluminum plates.

As a result of accelerator tests we have obtained the following parameters of the accelerated electron beam:

- output energy..6.5 MeV;
- average power of electron beam.............. 1.2 kW.

The operating frequency was 2797.3 MHz.

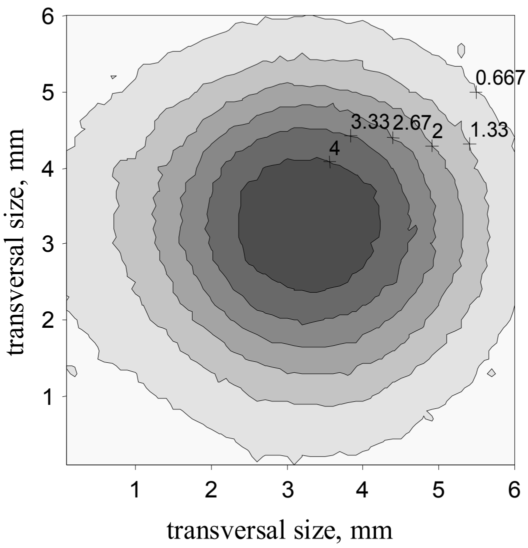

Fig. 2. Dose distribution of electron beam density at a distance 20 mm from the accelerator outlet foil.

4 CONCLUSION

The accelerator tests have demonstrated that calculation and experimentally measured characteristics of electron beam agree with each other.

The accelerator is made rather compact and has a relatively small weight that makes it suitable for implementing of a transportable variant. Besides, it possesses a sufficient power in order to be applied for radiography of large-scale objects and items with a large mass thickness in the real time mode.

Rise of the average power of accelerator's microwave supply up to 4 kW will permit an increase of the average power of accelerator's electron beam no less than up to 2 kW.

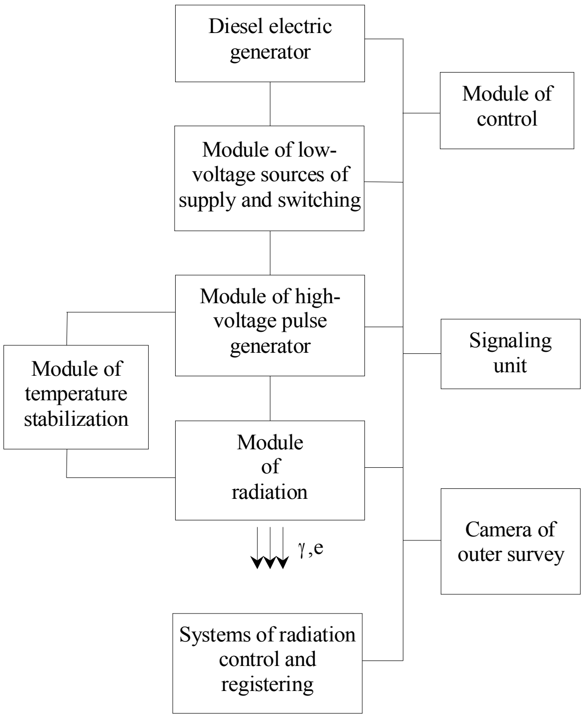

Fig. 3. Block-diagram of the radiography complex.

The new accelerator is supposed to be employed as a part of transportable radiography complex that will be able to solve the most wide range of problems: beginning with radiography of large-scale objects and ending with investigations and employment of radiation technologies in different fields.

The whole complex, for the sake of maintainability, will have a module structure. Each module will involve one or several accelerator's systems joined by a functional attribute. Modules will be either transportable or will possess media for convenient transportation.

To provide an independent electric supply, the complex will comprise a Diesel electric generator. Fig. 3 shows one of the variants of a radiography complex block-diagram.

The radiography complex can be transported by two trucks or by a railway platform.

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