THE FULL-SCALE MICROWAVE-STAND OF LUE-200 ACCELERATOR AT IREN FACILITY

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In the Frank Laboratory of Neutron Physics at JINR the 200 MEV linear electron accelerator (LUE-200) for a source of resonant neutrons (IREN) is under construction. It is based on the best world achievements in the area of accelerator engineering.

The rate of a set of particle energy in LUE will be 35 MeV/m and the pulse repetition rate will be 150 Hz. In the accelerator the most powerful klystrons such as 5045 class are used. System of capacity multiplication (SLED), developed for the Stanford electron-positron collider (SLAC), and modern accelerator sections are made in the Budker institute for nuclear physics (Novosibirsk). The research and development work is carried out in LNPh JINR. The full-scale microwave-stand klystrons 5045 with the modulator of the maximal pulse power 150 MW, maximal average power of 150 kW, charging voltage 50 kV, pulse repetition rate of 150 Hz, pulse duration of 5 μs [3] were fabricated.

This paper presents the results of the following works: development of the microwave-stand systems; klystron 5045 starting; investigation and upgrading of the modulator units, and perfection of operating conditions under the project IREN.

The full-scale microwave–stand klystron and modulator for IREN comprise:

- modulator involving a dual forming line with concentrated parameters (total capacity of condensers is 2x0.7 μsF and total inductance of adjustable coils of a L-type in each of unary lines is 45 μsH);
- digital thyratron TGI1-5000/50 ("ISPOLIN"), system of stabilization of charging voltage;
- klystron 5045 with the pulse transformer BIT [4];
- accelerator section with the system of capacity multiplication, waveguide and micro- wave loading;
- vacuum, water cooling, termostabilization, management and control systems.

The system of charging voltage stabilization of the modulator consisting of two basic devices is described in detail in [4].

The basic attention was given to calculation and measurement of parameters of a forming line of the modulator and a charge circuit such as resonant and resistance charge of a forming line, etc in the process of adjustment of the modulator to be operated on the pulse transformer klystron and increase of a target voltage of the modulator up to rating values. There the main disadvantages of the modulator were determined as a result of analysis of its operation such as a large own inductance of condensers of a type THEM – 100-a regular forming line of the modulator accelerator of the station " OLIVIN SU". Thus it was established, that the modulator operates in a stable mode on active loading of 4 Ohm down to the rated voltage (23 kV). However, one was not able to form a small negative emission (5-7%) which is necessary for tiratron closing at operation on inductive loading (the raising pulse transformer fails to be generated BIT).

Further for optimization of the work with the core KIU-12 used was the technique described in [4]. The new dual forming line is developed, computed (under the program Pspice) and mounted. The primary parameters of the forming line are: wave resistance 4 Ohm, pulse duration 5 μs (at a level 0.1 from amplitude), duration of a pulse flat top 3.5 μs (at a level 0.9). Small induction condensers K75-35 are applied with a nominal capacity 24 nF, at a voltage 50 kV, which were developed for the accelerator LIA-30 and are designed for operation at a frequency up to 50 Hz. The tests of a new forming line have shown its satisfactory quality when operation at a frequency up to 50 Hz. The debugging of the forming line and modulator was carried out as a whole at the following stages:

1) at a frequency of 2 Hz increase of the pulse voltage of the modulator up to 85 % of the face value (working voltage 20 kV, nominal 23.5 kV) and anode voltage of the klystron 320-330 kV, respectively;
2) correction of the pulse form of the modulator with the dual forming line at a total working voltage for contraction of fronts and formation of flat top of a pulse up to 4 μs;
3) smooth transition to the pulse repetition rate of 50 Hz.

Klystron 5045 has fulfilled more than 100 hours in total. The work proceeded more than 50% of time at the following parameters: a target voltage of the modulator 23.5 kV and frequency 50 Hz, voltage on the klystron 320–330 kV, complete current klystron 380-400 A, current of heat 26 A, current coral bias of BIT 12 A, current of the solenoid focussing 14 A.

The tests of the 5045 klystron in a mode of generation of a microwave - power on the coordinated microwave - loading are carried out. Loading is connected through the vacuum waveguide, which consists of:

- E-, H- rotary elements;
- Directed beam splitter for measurement of falling and reflected waves;
- Waveguide vacuum slide gate and means of vacuum pumping.

The serviceability of a system of preliminary excitation of the klystron, systems of synchronization, management and control, measuring devices, as well as the modulator M350 is checked up as the klystron operates in a mode of generation of a microwave - capacity.

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The working vacuum was achieved under pressure 4.8×10^{-5} Pa after long heating up to ~ 200°C, before microwave excitation on the klystron, in a microwave path.

The voltage on the klystron was increased up to 70% of the nominal one (from 242 kV to 350 kV) at a pulse repetition rate of the modulator of 2 Hz. The correction of a pulse form is carried out at a voltage on the modulator output with changing parameters of a forming line elements.

The system of preliminary klystron excitation is prepared, assembled and tested for the coordinated loading.

The microwave excitation supply on the klystron input is carried out after overlapping of klystron excitation pulses and klystron anode voltage controlling by a high-voltage divider BIT.

The microwave capacity is obtained on the coordinated klystron loading and equals ~ 30 MW when calibrating by a curve of the klystron 5045.

The technological part of the termostabilization system of the section is mounted. The electronic termostabilization system is developed on the basis of the programmed controller “906S Eurotherm controls” and 3 powerful tiristor blocks of 425A (3×5.5 kVA). The tests of the system are carried out and the programs of temperature PID - regulation are optimized. The decrease of stabilization errors and setting up of the temperature up to 0.03 – 0.05°C is performed in the process of system installing for ~ 20 min/°C.

The works on creation of a control system, blocking and emergency or precautionary signal system (CBS) are carried out. The development of a logic of the electronic system for blocking and protection of klystron inclusion is executed that supplements opportunities of the system CBS (or replaces its duplicating relays). The circuit developed has 3 modes: the control and record of the emergency data, diagnostics and the signal system, operative protection and blocking [5]. The system of computer monitoring of emergency signals CBS is created with the purpose of their registration and fast klystron protection. The module of the system CAMAC is created for protection and registration of 16 emergency thresholds, analog parameters (with given control point for temperature, vacuum, level of currents and voltage). The module provides fast blocking and protection of 4 channels on electrophysical parameters. The automatic switching-off of the start pulse and power supplies at disruptions in klystron and microwave decrease or increase of the anode voltage at pulsations because of failures in the system of a high-voltage feed etc. The system of modules provides fast blocking of pulses of the synchronizer of the start. Now an electronic and relay part of the system (CBS) of the stand "are sewed".

TESTS OF A PROTOTYPE OF THE ACCELERATING SECTION

The tests of a prototype of the accelerating structure (section of 3 m length) are carried out on the preinjector VEPP-5 at the Budker Institute of Nuclear Physics (BINP) [6]. The feature of circuit experiments was the presence of the second, "passive" accelerating section, the structure of which was loaded on a microwave - loading, thus the microwave power did not deliver to. The presence of a "passive" section brings to taking a significant part of a beam energy and to expansion of an energy spectrum of the accelerated particles.

The basic results of tests consist in the following:

The average acceleration rate achieves more than 35 MeV/m at acceleration of a beam electrons with a current of 2.3 A and duration ~ 5 ns.

The power characteristics of the beam accelerated are worsening at acceleration of a beam electrons with current and duration parameters close to beam parameters of the LUE-200 accelerator (current 1.5 A, duration 250 ns), the average energy of the beam decreases and the very wide power spectrum (Fig. 1) is formed.

Comparison of experimental results shows that at the output power of the klystron 50 MW at optimum buncher adjustment, the average (in a pulse) current of a beam accelerated in the first section reaches 1.35 A, the maximal energy of particles in a bunch reaches 105 MeV at a spectrum width of 30 MeV or 90 MeV at a spectrum width of 10 MeV.

Comparison of test results with design parameters is given in Table 1 in recalculation on one accelerating section.

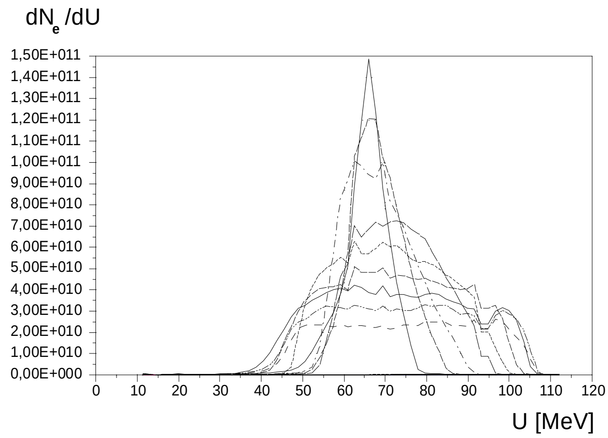

Fig. 1. A power spectrum of accelerated electrons with varying the time of gun energizing versus the pulse of microwave capacity.

Table 1

	Project IREN	Experiment
Pulse repetition rate F [Hz]	150	5
Energy quantity of a beam W_{beam} [D]	40	30
Pulse current of accelerated particle beam I_0 [A]	1.5	1.35
Klystron power P_{kl} [MW]	63	50
Maximal energy of a beam U_{beam} [MeV]	105	100
Duration of a current pulse τ_b [ns]	250	240

As Table 1 indicates, there were no design objectives of the accelerator LUE-200 carried out as a result of the experiment.

The average current of accelerated particles per a pulse 0 achieved at present is less by about 90% of the design one that basically defines shortage of energy quantity of a beam (~ 75% of the design one).

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