STATUS OF WORK ON 5 MeV 300 kW INDUSTRIAL ELECTRON ACCELERATOR PROTOTYPE*

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Abstract

New industrial accelerator prototype with electron energy up to 5 MeV, average beam power of 300 kW, and duty factor of 14% is under construction at Budker INP. At present, the design work is completed, the accelerating structure is under production at INP workshop. The paper presents a general description of the accelerator, its block diagram, and experimental results obtained at recent tests of the accelerating structure and injection unit.

INTRODUCTION

Since 1970, Budker Institute of Nuclear Physics SB RAS has been developing and manufacturing the ILU-type electron accelerators for the work in the research and industrial radiation-technological installations. Experience of development and maintenance of ILU accelerators has shown, that the single resonator systems with one accelerating gap can be effectively used for industrial accelerators with energies up to 5 MeV and average beam power up to 50–60 kW [1]–[3]. The increase of the electron efficiency of the accelerator evidently requires the use of systems with some accelerating gaps connected in series.

New industrial accelerator with electron energy up to 5 MeV, and average beam power of up to 300 kW, and duty factor of 14%, was designed basing on experience of work with the ILU accelerators [4].

ACCELERATOR OVERVIEW

The main accelerator elements are: accelerating structure, RF generator, triode electron gun, and X-ray converter (Fig.1). RF generator is a two-staged amplifier excited by a signal from the accelerating structure passed via phase shifter to provide the proper phase shift in the feedback circuit. TH628 diacrode is planned to be used in the power source final stage to obtain 3 MW of pulsed and 450 kW of average power. The diacrode has been tested at the ”Thales” workbench in 3 MW of pulsed and 600 kW of average power operating regime [4].

The accelerating structure (Fig.2) consists of five modules, which form three complete accelerating cells, two accelerating half-cells and four coupling cells. The structure is made of oxygen-free copper (Fig.3). Pulse power supply and control system, standard for all ILU accelerators, are used for developing this model also. The new machine is relatively simple in its production and adjustment.

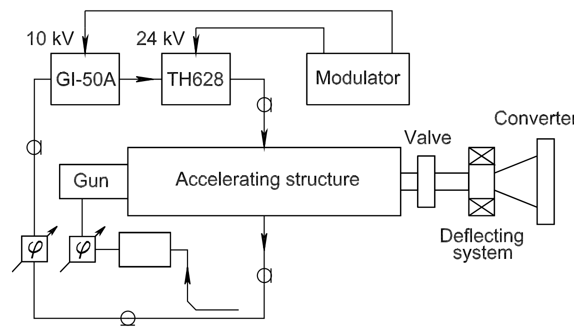

Figure 1: Accelerator block diagram.

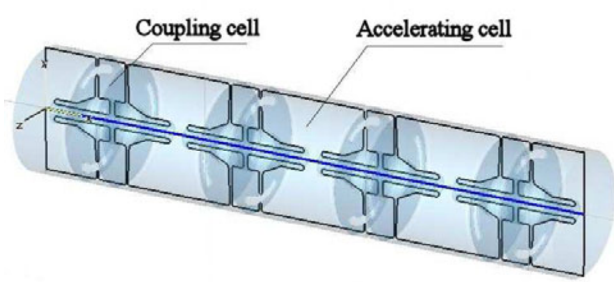

Figure 2: 3D view of the accelerating structure.

The electrons are accelerated in the low frequency multi-resonator standing wave structure with on-axis coupling resonators. This design makes it possible to decrease power losses in each resonator comparing with the single-resonator accelerator (at the same average beam power level) and to obtain the electron efficiency of the accelerator about 70%.

The electron beam is injected by the triode RF gun formed by a grid-cathode unit and the first accelerating gap. Such design allows to sufficiently simplify the beam injection system. The report presents the accelerator prototype overview and status of the project.

The pulse modulator generates the anode feeding voltage for the RF generator. Its pulse power should be about 6 MW at average power level of about 1 MW. The voltages

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Figure 3: Accelerating structure assembled in the bunker.

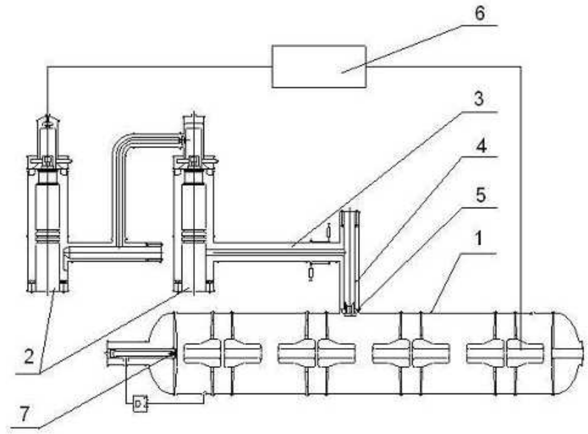

Figure 4: RF power supply scheme. 1 – accelerating structure, 2 – two stages on GI-50A triodes, 3 – output feeder, 4 – matching device, 5 – RF power input unit, 6 – phase shifter, 7 – RF triode gun.

are 24–26 kV and 10–12 kV for the output and prime stages respectively.

The electron beam is injected by the triode electron gun. An RF bias voltage is applied to its grid-cathode circuit to decrease electron energy spread in the beam. The RF bias voltage is shifted from the phase of the accelerating voltage, the shift value is adjusted by the phase shifter.

The X-ray converter is placed at accelerator output and serves for electron beam energy conversion into braking radiation (Bremsstrahlung).

TESTS OF THE ACCELERATOR PROTOTYPE

Testing of the accelerator prototype at beam energy of 5 MeV, pulsed power not less than 2 MW, and duty factor 1% requires an RF power source with output power of 2.75–3.0 MW (power losses in the accelerating structure may comprise 0.75 MW). Based on accumulated experience on ILU-type accelerators [3], a two-stage feeding scheme from an active oscillator has been chosen (see Fig.4).

The accelerating structure 1 is excited from the two-stage active oscillator 2 via aerial coaxial feeder 3, matching device 4, and power input 5. Input feedback signal is delivered from one of the accelerating structure cells through the feedback inductive loop, flexible coaxial cable, and mechanical phase shifter of trombone type or controlled ferrite phase shifter 6.

The two-stage scheme has been chosen to increase the output power, optimally tune the output stage, and lighten the phase shifter operating regime in the feedback circuit.

The RF generator based on triode tube type GI-50A has a pulse power up to 3 MW and 20–30 kW of average power. This generator is planned to be used for accelerator prototype testing. Successful tests on excitation of the single resonator similar to the tested accelerating structure from the output cascade of such generator are carried out.

BEAM INJECTION

It is supposed to use the internal beam injection from the cathode-grid unit, which is placed directly into the first accelerating gap. This concept permits us to sufficiently simplify the design and reduce the cost of accelerator respectively, as well as to improve its reliability and reduce the maintenance charges.

The cathode-grid unit (see Fig.5) has been designed and manufactured, and is under testing. The grid and electrode are the united peace made of copper. The cathode unit is installed on the insulator ahead of the grid. The 20 mm diameter cathode tablet is made of lanthanum hexaboride (LaB_6). The cathode heating is provided by a cone helix heater made of tungsten wire of 0.6 mm diameter heated by current of 20 amperes, the operating voltage is 12–15 V.

As mentioned above, use of the internal injection, when the cathode with the control grid is placed directly at the accelerating gap entrance, is the intrinsic feature of the ILU-type accelerators. The opposite electrode of the cavity is used as an anode.

The grid-cathode unit operating in regime ‘C’ will allow us to avoid an additional grid heating because of impacts of the direct beam electrons and also to easily control the amplitude, duration and phase of the current. Here, the constant backing voltage on the cathode with respect to the grid will allow to control the average beam current. Applying an additional RF voltage with the amplitude not higher than the constant bias, with the proper phase shift will allow us to select the optimal amplitude, duration, and phase of beam bunch injection into the accelerating channel. So, the back electrons, which pass the grid at unfavorable accelerating field phases and return to the cathode with noticeable

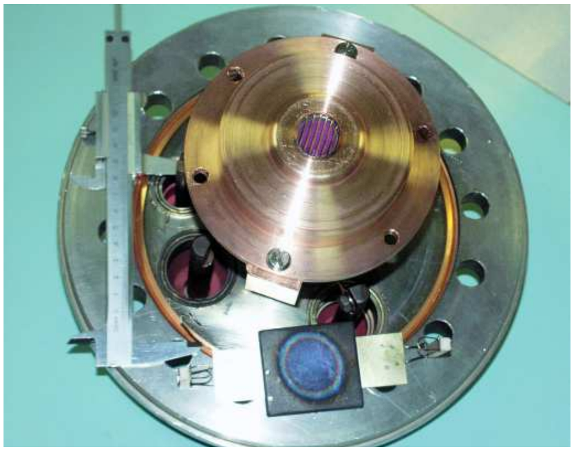

Figure 5: Cathode-grid unit.

energies, may be practically eliminated.

To check the possibility to correct the electron energy spectrum by applying the RF bias voltage to the cathode-grid gap the measurements were carried out on the existing linear RF accelerator ILU-10 [2] at energy of 5 MeV and beam power of 50 kW .

Experimental data obtained from beam spectral characteristics measurements at ILU-10 output at the constant grid-cathode bias (1) and with the use of the additional voltage of the operating frequency (2) are presented in Fig.6.

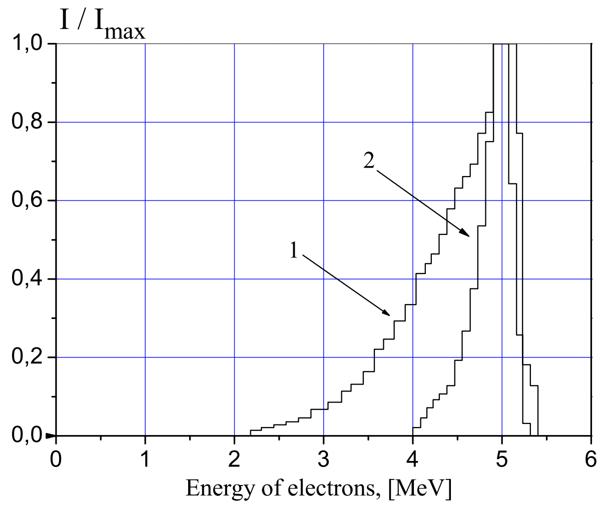

Figure 6: Experimental spectrum of beam electrons.

CONCLUSION

At present, the status of process on the high-power industrial accelerator prototype creation is as follows:

- accelerating structure has been developed, manufactured, and is under assembling it the radiation bunker;
- cathode-grid unit has been developed, produced, and tested;
- beam internal injection and dynamics in the accelerator have been numerically modeled [6], effect of coupling slots on beam dynamics has been estimated [7];
- possibility to improve the beam energy spectrum has been experimentally proven;
- RF multipactor discharge has been experimentally suppressed for stand cavity with dimensions similar to a single accelerating cell of the prototype accelerating structure;
- RF power input has been assembled and is under multipactor conditioning;
- the work is underway on development of TiN coating technology for inner surfaces of the accelerating structure units;
- control equipment has been produced and installed in the control room.

REFERENCES

[1] V.L. Auslender. ILU-type electron accelerator for industrial technologies. Nuclear Instruments and Methods in Physical research, B 89 (1984), pp. 46–48.

[2] V.L. Auslender et al. Electron Accelerator for Energy up to 5.0 MeV and Beam Power up to 50 kW with X-Ray Convertor. PROBLEMS of ATOMIC SIENCE and TECHOLOGY, 2004, #1. Series: Nuclear Physics Investigations (42), pp. 21–23.

[3] V.L. Auslender. ILU-type Electron Accelerators for Industrial Technologies. Nuclear Instruments and Methods in Physical Research B89 (1994) pp. 46–48.

[4] V. Auslender et al., “High Power Electron Accelerator Prototype”, Proc. of PAC’05, Knoxville TN, 2005, pp. 1502–1504.

[5] J. Lyles, C. Fredrichs, M. Lynch, “New High Power 200 MHz RF System for the LANSCE Drift Tube Linac”, Proc. of X1X International Linac Conference, Chicago, 1998, pp. 231–233.

[6] M. Tiunov et al. “Modeling of Internal Injection and Beam Dynamics for High Power RF Accelerators”, Proc. of PAC’05, Knoxville TN, 2005, pp. 1419–1421.

[7] V. Tarnetsky et al. “Numerical Study of Coupling Slot Effect on Beam Dynamics in Industrial Accelerator Prototype”, Proc. of PAC’05, Knoxville TN, 2005, pp. 1622–1624.