WORK STATUS OF 5 MeV 300 kW ELECTRON ACCELERATOR

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Design work has been completed for the accelerating structure of high-power electron accelerator with 5 MeV, 300 kW, 176 MHz parameters. The structure is being produced in BINP workshop. The paper presents the design of the accelerating structure which consists of a chain of coaxial cavities, and block diagram of experimental workbench. Structure of the main accelerator blocks and their degree of fabrication are viewed.

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1. INTRODUCTION

Currently some interest has been aroused in X-ray radiation technologies because of the high penetration ability of X-rays. This is of particular importance for pasteurization of wide spectrum of food products, disinfection of mail deliveries, and some other applications.

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.

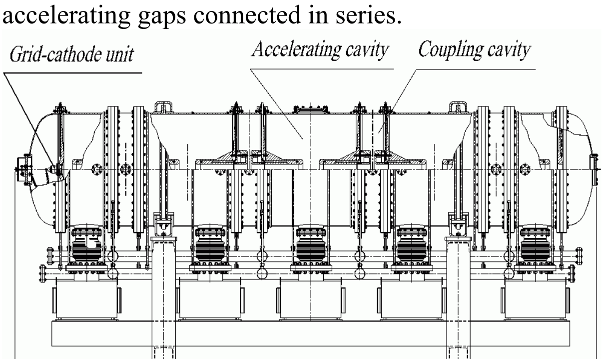

Fig.1. General view of accelerating structure

A 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 [1-3].

The design of its accelerating system is shown in Fig.1. The accelerating structure consists of five modules and forms three complete accelerating cells, two accelerating half-cells and four coupling cells. The structure is made of oxygen-free copper (Fig.2). A pulse power supply and control system, standard for all ILU accelerators, is used for developing of this model also. The new machine is relatively simple in its production and adjustment.

Electrons are accelerated in a 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 a single-resonator accelerator (at the same average beam power level) and to obtain the electron efficiency of the accelerator about 70%.

Fig.2. Disk of accelerating structure during manufacturing

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

2. GENERAL DESCRIPTION OF ACCELERATOR

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

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 are 24…26 kV and 10…12 kV for the output and input stages, respectively.

An electron beam is injected by the triode electron gun. An RF bias voltage is applied to a grid-cathode circuit to decrease an electron energy spread of 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 the accelerator output and serves for electron beam energy conversion into a braking radiation (Bremsstrahlung).

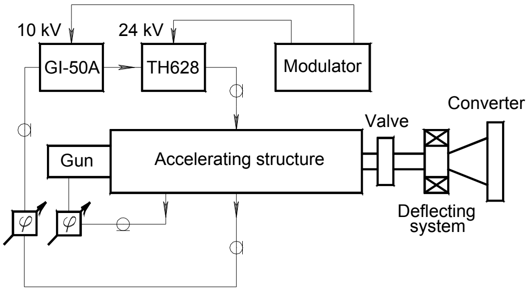

Fig.3. Accelerator block diagram

3. 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 comprise 0.75 MW). Based on accumulated experience on ILU-type accelerators [1], a two-stage feeding scheme from an active oscillator has been chosen (see Fig.4).

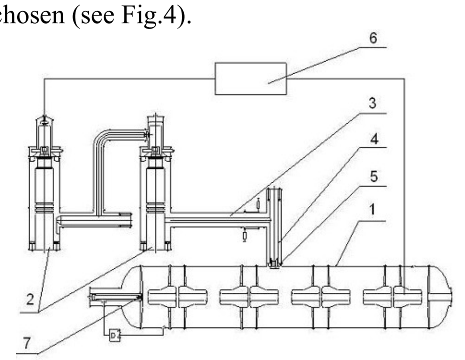

Fig.4. RF power supply of the prototype accelerator. 1 - accelerating structure; 2 – two stages on GI-50A triodes; 3 – output feeder; 4 – matching device; 5 – RF power input unit;, 6 – phase shifter; 7 – RF triode gun

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

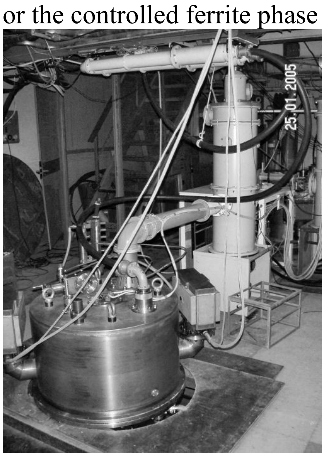

Fig.5. Output cascade of RF generator with single resonator

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

The RF generator based on a 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 the use for accelerator prototype testing. Successful tests on an excitation of a single resonator similar to the tested accelerating structure are carried out (Fig.5).

4. BEAM INJECTION

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

The grid-cathode unit, being assembled as a single unit made of copper (Fig.6), is designed, manufactured, and tested. 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 A, the operating voltage is 12…15 V.

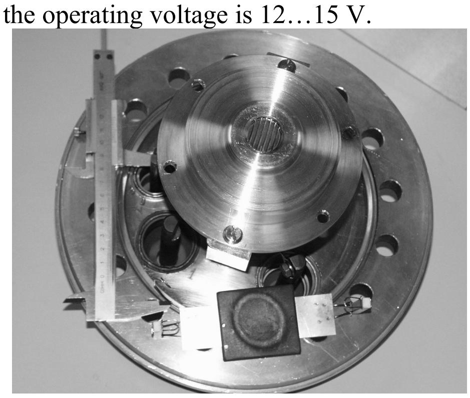

Fig.6. Grid-cathode unit

As mentioned above, the 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 additional grid heating because of impacts of the direct beam electrons and also to easily control amplitude, duration and phase of the current. Here, the constant backing voltage on the cathode with respect to the grid will allow us to control the average beam current. An application of an additional voltage at the main, second, or third harmonics with an amplitude not higher than the constant bias, and with a proper phase shift will allow us to select the optimal amplitude, duration, and phase of beam bunch injection into the accelerating channel. So, the number of back electrons, which pass the grid at unfavorable accelerating field phases and return to the cathode with noticeable energies, may be either almost zero (for the main and second harmonics) or significantly decreased (for the third harmonic).

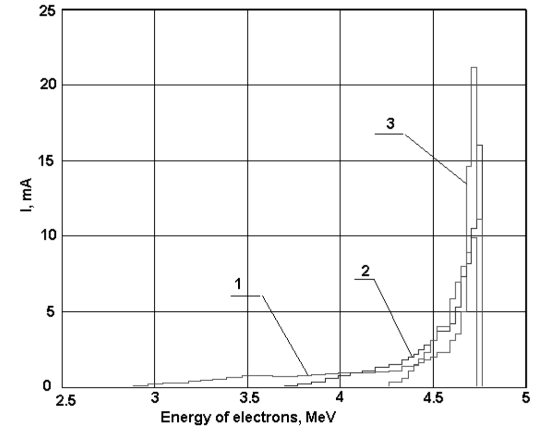

Fig.7. Experimental spectrum of beam electrons

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

Fig.7 presents experimental data obtained from the measurements of the beam spectral characteristics at the ILU-10 output for the case of the constant grid-cathode bias applied (1) and the use of the first (2) and third (3) harmonics.

5. CONCLUSION

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

- the accelerating structure has been developed and now is under manufacturing process;
- the cathode-grid unit has been developed, produced, and tested;
- the beam internal injection and dynamics in the accelerator has been numerically modeled, the effect of coupling slots on the beam dynamics has been estimated;
- the possibility for improvement of the beam energy spectrum has been experimentally proven;
- the RF multipactor discharge has been experimentally suppressed in a stand cavity with dimensions closed to a single accelerating cell of the prototype accelerating structure;
- the work on development of TiN coating technology for inner surfaces of the accelerating structure units is underway.

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СТАТУС РАБОТ ПО ЭЛЕКТРОННОМУ УСКОРИТЕЛЮ 5 МэВ 300 кВт

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Закончены проектные работы по ускоряющей структуре мощного электронного ускорителя 5 МэВ, 300 кВт, 176 МГц и ведется ее изготовление в опытном производстве Института. Дается описание конструкции ускоряющей структуры, состоящей из цепочки связанных коаксиальных резонаторов. Приводится блок-схема испытательного стенда, рассматривается устройство отдельных узлов ускорителя и состояние их готовности.

СТАТУС РОБІТ З ЕЛЕКТРОННОГО ПРИСКОРЮВАЧА 5 МеВ 300 кВт

В.Л. Ауслендер, К.Н. Чернов, В.Г. Ческідов, Б.Л. Факторович, В.А. Горбунов, І.В. Горнаков, І.В. Казарезов, М.В. Коробейніков, Г.І. Кузнецов, А.Н. Лукін, І.Г. Макаров, С.А. Максімов, Н.В. Матяш, Г.Н. Острейко, А.Д.Панфілов, Г.В. Сердобінцев, А.В. Сидоров, В.В. Тарнецький, М.А. Тіунов, В.О. Ткаченко, А.А. Тувік

Закінчено проектні роботи із прискорювальної структури потужного електронного прискорювача 5 МеВ, 300 кВт, 176 МГц і ведеться її виготовлення в дослідному виробництві інституту. Дається опис конструкції прискорювальної структури, що складається з ланцюжка зв'язаних коаксіальних резонаторів. Приводиться блок-схема іспитового стенда, розглядається будова окремих вузлів прискорювача і стан їх готовності.