# PROGRESS IN CW MODE ELECTRON RESONANCE ACCELERATOR BETA-8 DEVELOPMENT

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*Abstract*

The progress in mode high-power resonance accelerator BETA-8 is presented. The accelerator operates in the mode of electron beam continuous generation and is aimed at performing radiation researches. Basic parameters of the accelerator are as follows: electron beam variable output energy 1.5 – 7.5 MeV, beam average power up to 300 kW, operating resonance frequency ≈ 100 MHz.

There were developed, produced and tested basic components of the accelerator [1]. The HF characteristics of coaxial cavity assembled with a unit of HF power input (UPI) at a low RF power level were measured. Three modules of RF generator the output power of each of them being 180 kW and the device of their power summation were tested. HF injector with electron energy up to 100keV was tested. There was developed the pattern of accelerated electrons transport making it possible to fulfill up to five successive passes through the accelerating cavity. Operative embodiments of deflecting electromagnets were designed and produced.

## INTRODUCTION

Electron accelerator BETA-8 is developed to implement radiation researches and radiation tests of large-size objects in a wide energy range of accelerated electrons. It will be possible to study and elaborate with its aid the technological processes requiring high power and high values of absorbed dose of electron radiation and bremsstrahlung.

The accelerator design parameters are as follows:

- Range of accelerated electron output energy – 1.5 ÷ 7.5 MeV;
- Maximum average power of the beam– 300 kW;
- Operating resonance frequency – 100 MHz;
- Modes of operation – continuous mode and pulse-periodic regime.

## TESTING OF ACCELERATOR BETA-8 SYSTEMS OPERATION

At the first stage there were performed all preparative activities in testing the systems of the accelerator which is characterized by the accelerating cavity power supply from one of the three HF generator modules. Electrons acceleration is fulfilled in a half-wave coaxial cavity (Fig.1) similar to that described in paper [2].

To the cavity there are connected the required technological systems: vacuumization system, water- and air-cooling system that make it possible to train the standard mode of operation. The elements of the channel of HF power transfer – coaxial HF feeder and unit of HF power input (UPI) – are used to feed the cavity from one generator module with the average power up to 180kW. At this level of HF supply power there can be generated a beam of accelerated electrons with the average power up to 15 kW and energy up to 7.5 MeV what is enough for experimental verification of the possibility of achieving basic design objectives.


Figure 1: Accelerator BETA-8: 1 – accelerating cavity; 2 – exhaust cart.

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### *System of the Accelerator HF Power Supply*

The system of HF power supply is designed to get continuous HF power of 540 kW as well as to synchronize its operation with HF injector. HF generator represents three single type generator modules [3] and HF power combiner (Fig. 2). The generator module is a multi-stage amplifier of HF power its preliminary stage being produced on tetrode GU-92A while the output one – on tetrode GU-101A.

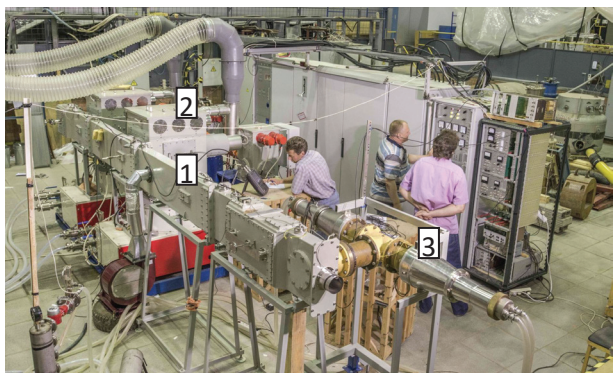


Figure 2: System of HF power supply: 1 – HF power combiner; 2 – generator module; 3 – matched load.

There was performed a matched load test for the generators. At operating on resonance frequency the measured power constituted 180 kW.

### *UPI and Channel of HF Power Transfer*

The developed unit of HF power input (UPI) makes it possible to match HF power transfer from the generator to the accelerating cavity through HF channel power transfer. UPI can operate on the frequencies in the range from 98 to 102 MHz the interface level being no worse than 1.3. The maximal HF power transferred through UPI in the modes of pulsed and continuous generation is estimated to be 600 kW. The external view of UPI is presented in Fig. 3.

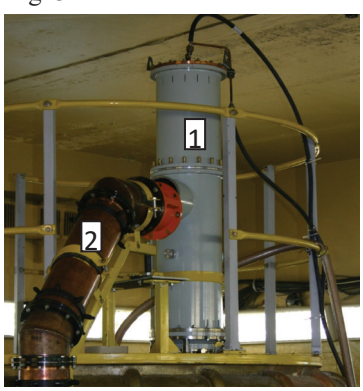


Figure 3: External view of UPI: 1 – UPI; 2 – channel of HF power transfer.

The channel of HF power transfer is developed on the base of air-filled coaxial waveguide the wave resistance being 50 Ω.

### *HF Injector*

The grid controlled thermo-cathode HF gun based on a quarter wave coaxial cavity operating on the frequency of 100 MHz (Fig. 4) is a basic unit of the injector.

The HF injector [4] accelerates electrons up to the required energies (50 ÷ 100) keV with the average current in the continuous mode up to 40 мА and regulated bunch repetition rate (0.01–100) MHz. Thereafter the electron beam is additionally formed in the transport channel with the aid of magnetic quadrupoles and then achieves the accelerating field of the cavity.

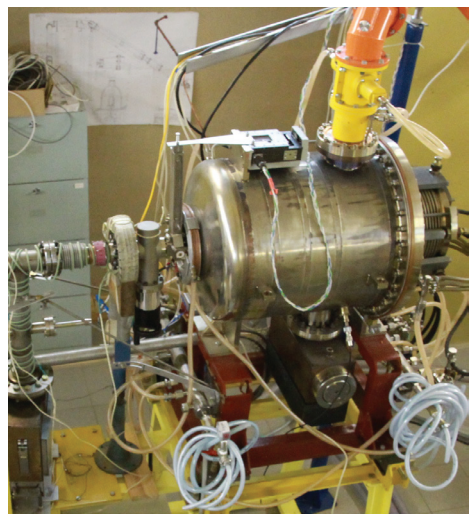

Figure 4: HF injector of electrons.

### *Accelerator Technological Systems*

There was tested the system of accelerator cavity vaccuumization – the achieved in the system vacuum constituted $10^{-5}$ Pa. Two similar exhaust carts connected to the accelerator cavity make it also possible to evacuate vacuum channels of beam transport and extraction.

The system of water cooling and thermal stabilization is designed to remove heat power excess up to 400 kW from the accelerator (cavity, HF generator etc.) and to maintain the preset temperature with the accuracy up to ±1°C.

For remote control and technological process inspection there was developed the automated control system and the system of accelerator control on the base of industrial computer.

## DEVELOPMENT OF A SYSTEM OF ELECTRON BEAM MAGNETIC GUIDANCE IN ACCELERATOR BETA-8

The acceleration of electrons was implemented at multiple pass of the cavity through a medial plane [4]. The cavity is computed so that at HF power supply there is formed in it the accelerating electric field increasing the energy of electrons by ≈ 1.5 MeV per one pass. The return of the beam to the cavity is provided by deflecting magnets arranged outside the cavity body.



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Fig. 5 demonstrates the computed trajectory of the beam in the cavity and magnetic system of transport for each of the operating energy values. A 3D model of accelerating cavity and the system of beam magnetic guidance is available in Fig. 6.

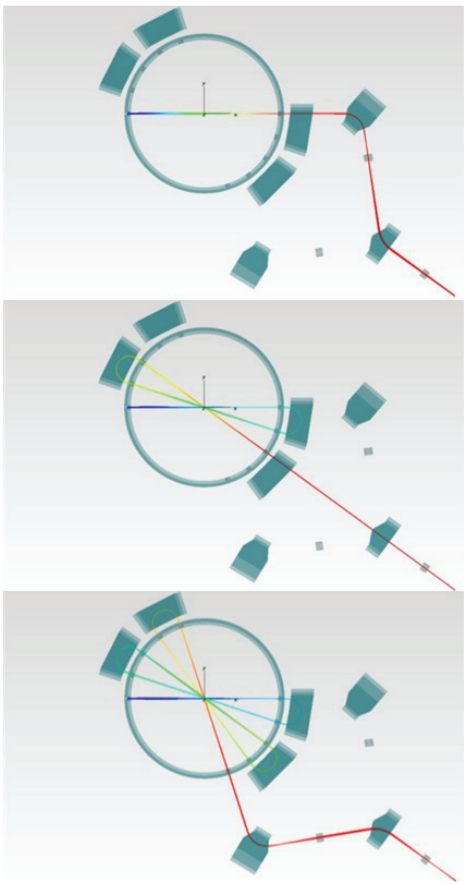


Figure 5: Three versions of electron beam computed trajectories for the following output energies: (a) – 1.5 MeV; (b) – 4.5 MeV; (c) – 7.5 MeV

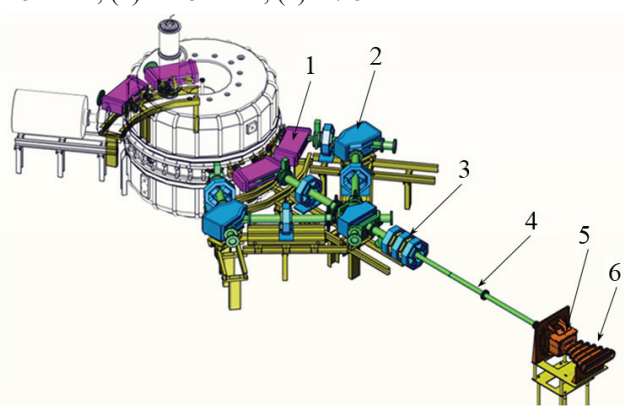


Figure 6: System of beam magnetic guidance:1 – magnets of (responsible for) beam recycling; 2 – beam transport magnets; 3 – quadrupole lenses; 4 – vacuum channel of beam guidance; 5 – scanning magnet; 6 – vacuum faucet.

At guiding a high-power beam the losses of electrons in the walls of the cavity and vacuum chambers are being constantly controlled by the automated management system with the aid of thermocouple sensors located in most critical points. The undertaken numerical three-dimensional calculations demonstrated that at beam diameter equal to (10 – 15) mm the transverse emittance should not exceed 50 mm·mrad, while the width of spectrum is – 0.1 MeV. Having provided these conditions one can implement five-fold acceleration of electron beam and its extraction to the irradiation area.

## CONCLUSION

There is described the stage of creating accelerator BETA-8 on which at decreased values of HF supply power (up to 180 kW) and electron beam there should be experimentally elaborated key physical principles of the accelerator operation. At this stage there were implemented the installation and testing of basic accelerator assemblies: accelerating cavity with UPI, one module of HF generator and HF injector. The required technological systems of the accelerator were also developed and tested so that stable design parameters are achieved at the operation with the automated system of management and control.

The developed system of electron beam magnetic guidance in accelerator BETA-8 is described. There are described as well the computed beam trajectories for each of the operating energy values: 1.5, 4.5 and 7.5 MeV, obtained as a result of three-dimensional simulation of electron dynamics in the accelerator.

After this stage is completed the BETA-8 accelerator can be taken to design output parameters through the increase of HF supply power up to the expected level of 540 kW.

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