A CW ELECTRON ACCELERATOR. THE PLANNED DESIGN AND ELECTROPHYSICAL CHARACTERISTICS

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This paper presents a project on a CW high-power electron accelerator. The main part of the accelerator consists of half-wave coaxial cavity resonator. The increment of electron energy is reached by repeated passing of an electron beam via full diameter of the cavity in median plain dividing its bulk into halves. Successive redirection of the electron beam into the cavity is performed by means of two rotary magnets. These magnets are placed outside the cavity. Main parameters of the accelerator are as follows: electron beam energy 1.5…7.5 MeV, average beam power above 300 kW, operating frequency 100 MHz.

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1. INTRODUCTION

High-power radiation complex based on an electron accelerator with wide range of accelerated electrons energy is developed in RFNC-VNIIEF. The main constituent of this projectible facility is λ/2 coaxial cavity where a standings wave of TEM type is excited. The operating principle of the accelerator is based on consecutive (step-by-step) electron beam passages via full diameter of the coaxial cavity in median plain dividing its bulk into halves. The traveling direction and electron velocity are synchronized with accelerating phase of HF electromagnetic field inside accelerating part of the cavity. The acceleration scheme, in which an electron beam is subjected to N passes through the cavity at an accelerating voltage U, is proposed. This allows increasing an electron energy pro rata U·N. The successive redirection of electron beam into the cavity is performed by two rotary magnets. These magnets are situated outside the cavity. The similar electron accelerators based on coaxial resonators and operated on an identical acceleration mode have been manufactured by IBA Company (Belgium). The type of these accelerators is RHODOTRON [1,2].

The output parameters of the project accelerator are as follows:

energy – 1.5…7.5 MeV;
average beam power – above 300 kW;
operating frequency – 100 MHz;
max. number of electron beam passes via full diameter of coaxial cavity – 5.

2. ACCELERATING COAXIAL CAVITY

2.1. ELECTRODYNAMIC CHARACTERISTICS OF THE CAVITY

Fig.1 shows the geometry of cavity interior surface. This geometry is a result of successive approximations obtained by numerical simulations. These computations are performed with the SUPERFISH program. The main criterion for the cavity geometry selection is a resonance eigenfrequency. The scheme for the electron beam acceleration at operating frequency 100 MHz has been calculated. The value of resonance eigenfrequency for chosen cavity geometry is 99.9 MHz.

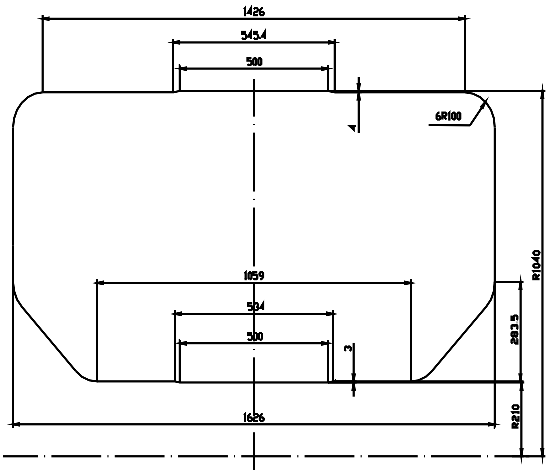

Fig.1. Longitudinal cross-section of the coaxial cavity

Fig.2 presents calculated distribution diagram for electric field lines within the cavity.

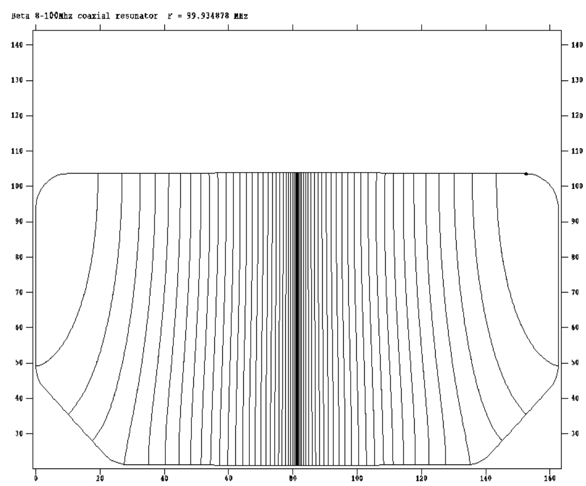

Fig.2. Distribution diagram of the electric field lines within the cavity

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These are the computational electrodynamic characteristics of the cavity:

Operating frequency, MHz	99.9
Power dissipation, kW.	160
Quality factor	39270
Maximum E, MV/m.	3,5

2.2. CAVITY DESIGN

The cavity body (Fig.3) is modular and consists of three parts. Two parts are cup-shaped. Being in an assembly they constitute the exterior part of the cavity body, while the third part, a central insertion, is located inside.

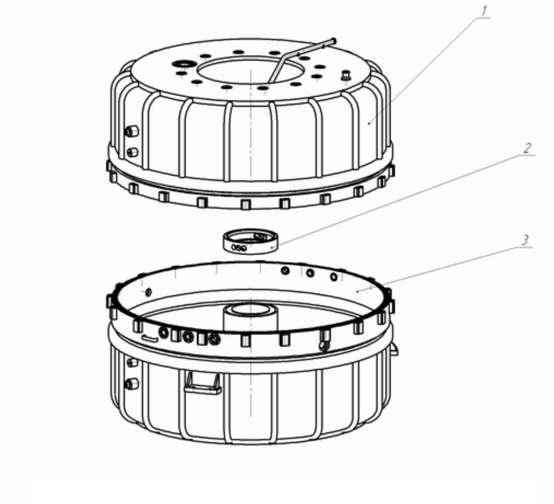

Fig.3. The cavity (isometry, disassembled view): 1– upper half-body; 2 – central ring; 3 – lower half-body

All three parts of the body are made of steel sheets (material – low-carbon steel, St.10 grade) by welding and shaped in an appropriate manner by metal forming or machining. The thickness of cavity body and its separate constituents meet necessary strength and thermal requirements. The internal surface of cavity body is electroplated with copper. The copper layer thickness is 50 microns. In the upper part of cavity body there are several nodes for HF power input and one node providing connection with a gagging sensor. In the lower part of cavity body there are nodes for the connection with the vacuum system and system for electron beam extraction from the cavity. For body cooling a water jacket is used providing direct contact of a refrigerant with the body exterior surface. The refrigerant is distilled water that circulates in the closed loop of cooling system.

3. THE SYSTEM OF BEAM TRANSPORTATION

The system of electron beam transportation consists of initial and two rotary constant electromagnets located on the exterior cavity wall. These magnets change a motion path of charged particles so that they perform 5 consecutive passings of full cavity diameter (Fig.4).

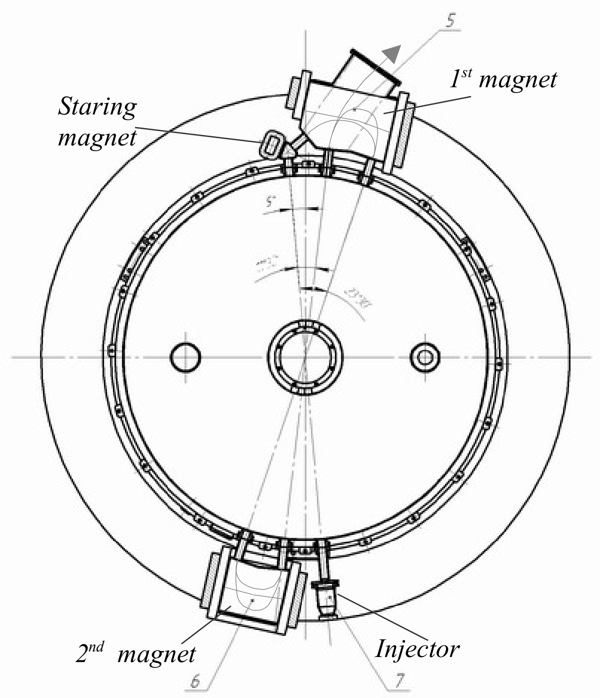

Fig.4. The cross-section of the cavity magnet system

In this case electrons are injected into the cavity by an electron gun (with initial energy 50 keV), pass along full exterior diameter of the cavity, and fall into the supplementary starting magnet. The field induction of given magnet is $B_0 = 0.073$ T. So, when straightforward electrons are falling into perpendicular magnetic field B_0, they start orbiting up to output edge of initial magnet. Here they are influenced by the field of one of the first rotary magnet parts (B_1^1 =0.029 T) that changes their motion path so that the beam enters the cavity again. After the next passing through the cavity, the electrons get into the first part of the 2nd rotary magnet (B_2^1 =0.15 T) that reverses their trajectory and turns electrons back into the cavity. Then electrons pass sequentially the first and second part of the first rotary magnet (B_1^2=0.079 T), return to the cavity, then pass through the first and second part of the second rotary magnet (B_2^2=0.2 T), come back to the cavity again, pass through it, then pass through the first rotary magnet, and fall into the system of electron beam extraction. Both rotary magnets are identical. Fig.5 presents the design variant for the second rotary magnet.

Inside the magnet there is a vacuum chamber joined with the lower half-body of the cavity by two sockets. The magnet consists of a basic coil (two windings top and bottom ones) and an alignment coil (two windings top and bottom ones). The magnet core consists of four sides: left-hand, right-hand, top and bottom ones. Top and bottom sides have variable geometry in their thickness. These swells provide the possibility of stepwise regulation of magnetic induction level. With each passage through the cavity, the electron energy increment is 1.5 MeV. After five full passages through the cavity, the electron energy becomes 7.5 MeV. The disconnection of

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1 – vacuum chamber; 2 – winding 1; 3 – core 1;
4 – compensating winding 1; 5 – winding 2; 6 – core 2;
7 – compensating winding 2; 8 – side 1; 9 – side 2

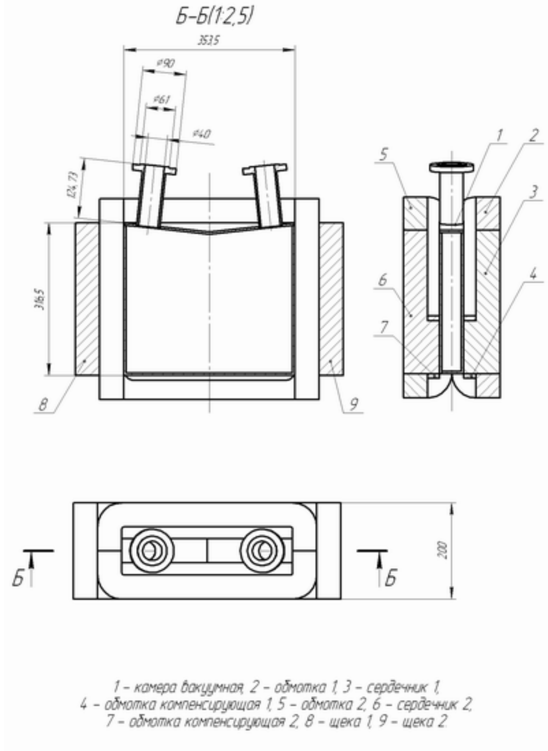

Fig.5. 2nd rotary magnet

various parts of the first rotary magnet makes it possible to extract from the accelerator electron beams with different output energy (from 1.5 up to 7.5 MeV) in one direction.

4. RF POWER SOURCE

RF power supply design is made by "TIRA" corporation (Saint-Petersburg city, Russia). According to requirements' specification, the necessary basic parameters of RF-generator are:

frequency range…………………95…105 MHz;
frequency fluctuation……………$5 \cdot 10^{-6}$;
RF output coaxial feeder (wave impedance 50 Ohm);
min. value of traveling-wave ratio.............. 0.7;
output power under optimum load.............. 500 kW;
operating mode of the RF power supply:
general mode – CW, training – pulsed with repetition rate 50…100 Hz and pulse width 0.1…2.0 ms;
harmonics level of output signal not above 30 dB;
amplitude instability at load equivalent ±0.1%;
feeding at 380 V three-phase electrical network.

A few high-power tetrodes GU-101A are intended to be used at the final stage of RF power supply. The input of RF power into the cavity is performed by a quarter-wave loop.

5. CONCLUSION

This paper presents the project on the CW high-power electron accelerator. The main part of accelerator is the half-wave coaxial cavity resonator. The cavity design and accelerating scheme are described. The main output parameters of the project accelerator are as follows: adjustable output energy of accelerated electrons – 1.5…7.5 MeV, average beam power – above 300 kW, operating resonance frequency – 100 MHz.

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ЭЛЕКТРОННЫЙ УСКОРИТЕЛЬ НЕПРЕРЫВНОГО ДЕЙСТВИЯ. ПРОЕКТНЫЕ, КОНСТРУКТИВНЫЕ И ЭЛЕКТРОФИЗИЧЕСКИЕ ХАРАКТЕРИСТИКИ

Н.В. Завьялов, С.А. Железов, С.Т. Назаренко, В.В. Порхаев, В.Т. Пунин, С.А. Путевской, М.Л. Сметанин, А.В. Тельнов

Представлен проект высокомощного ускорителя электронов непрерывного действия. Основной частью ускорителя является полуволновой коаксиальный резонатор. Увеличение энергии электронов осуществляется при последовательном прохождении пучком полного диаметра коаксиального резонатора в делящей его объем пополам поперечной медианной плоскости. Перенаправление движения электронного пучка в резонатор происходит при помощи двух поворотных магнитов, которые размещены вне резонатора. Основные параметры ускорителя: энергия электронного пучка 1.5…7.5 МэВ, средняя мощность пучка 300 кВт, рабочая частота 100 МГц.

ЕЛЕКТРОННИЙ ПРИСКОРЮВАЧ БЕЗПЕРЕРВНОЇ ДІЇ. ПРОЕКТНІ, КОНСТРУКТИВНІ І ЕЛЕКТРОФІЗИЧНІ ХАРАКТЕРИСТИКИ

М.В. Завьялов, С.А. Железов, С.Т. Назаренко, В.В. Порхаєв, В.Т. Пунін, С.А. Путевськой, М.Л. Сметанін, А.В. Тельнов

Представлено проект високопотужного прискорювача електронів безперервної дії. Основною частиною прискорювача є півхвильовий коаксіальний резонатор. Збільшення енергії електронів здійснюється при послідовному проходженні електронним пучком повного діаметра резонатора в середній площині, що ділить його об’єм навпіл. Перенапрямок руху електронного пучка в резонатор відбувається за допомогою двох поворотних магнітів, які розміщені поза резонатором. Основні параметри прискорювача: енергія електронного пучка 1.5...7.5 МеВ, середня потужність пучка 300 кВт, робоча частота 100 МГц.