РОСАТОМ

ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

РФЯЦ
ВНИИЭФ

STATUS REPORT OF DEVELOPMENT OF HIGH POWER BEAM CW ELECTRON ACCELERATOR

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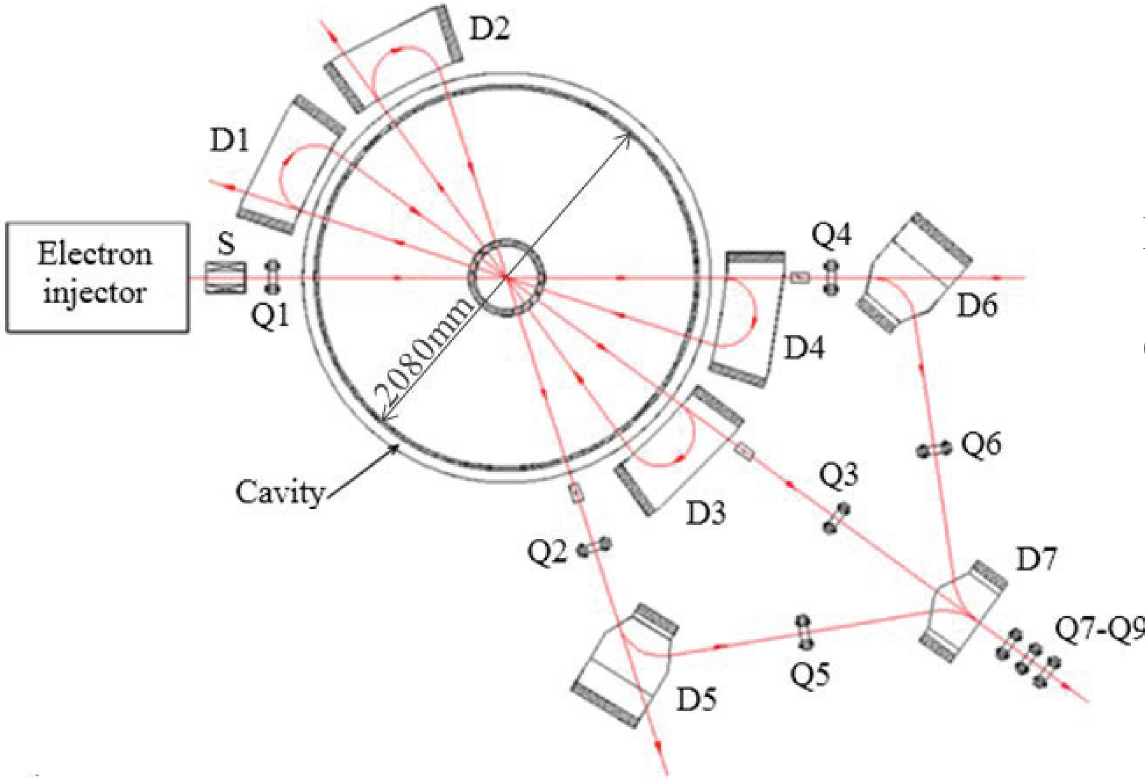
Introduction

- The accelerator has been designed for technological process testing required high values of beam power and absorbed dose of electron radiation and bremsstrahlung
- The principle of acceleration is based on multiple passes of electron beam through the accelerating gaps of coaxial half-wavelength cavity on the level of median plane where the magnetic component of RF field is entirely absent
- The maximal electron energy of 7.5 MeV is achieved after five passes of electron beam through the accelerating cavity.

Scheme of the acceleration and basic design objectives

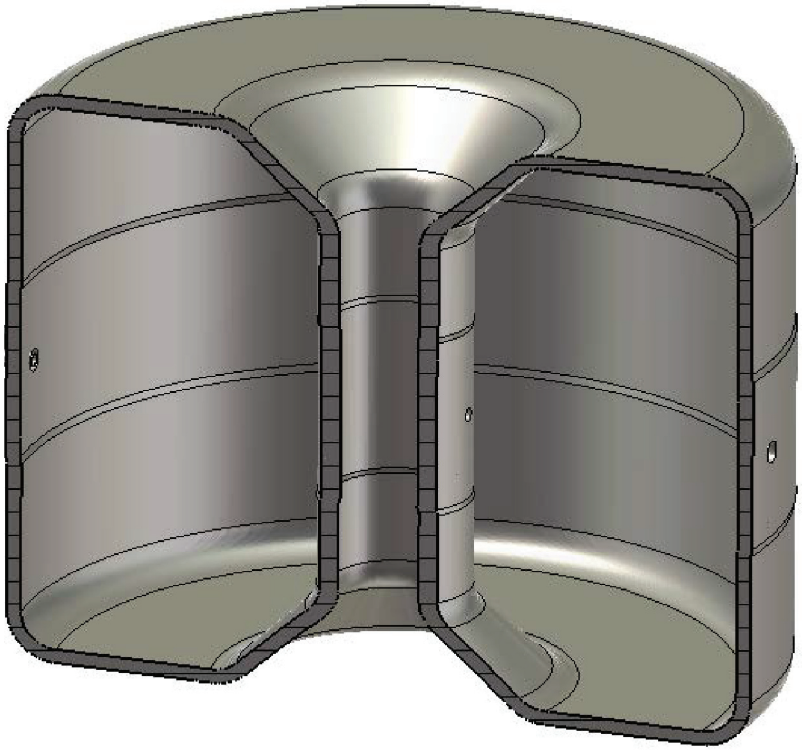


D1 – D7 – bending dipole magnets
S – focusing solenoid
Q1 – Q9 – quadrupole magnetic lenses

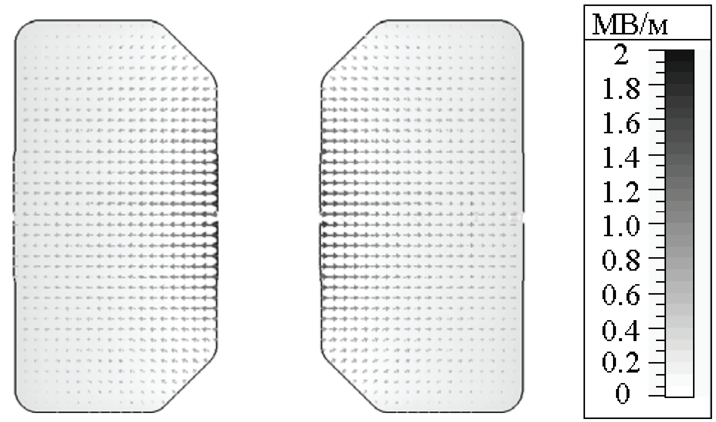
- Output electron energy.......................................1.5, 4.5, 7.5 MeV
- Maximal average power of electron beam...........300 kW
- Operating resonance frequency…………………100 MHz
- Average current…………………………………up to 40 mA
- Operating modes…..…......................continuous and pulse-periodic

Basic accelerator components

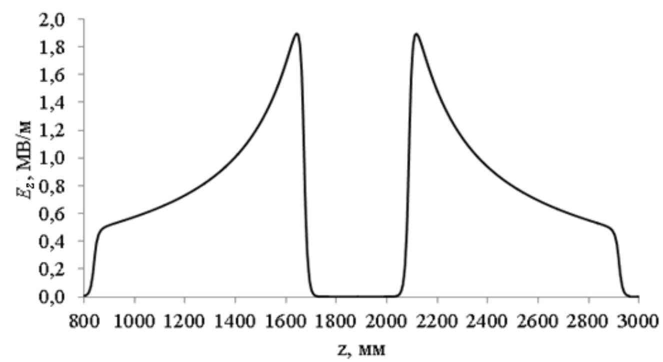
Accelerating cavity



3*D*-model of the cavity



Electric field distribution

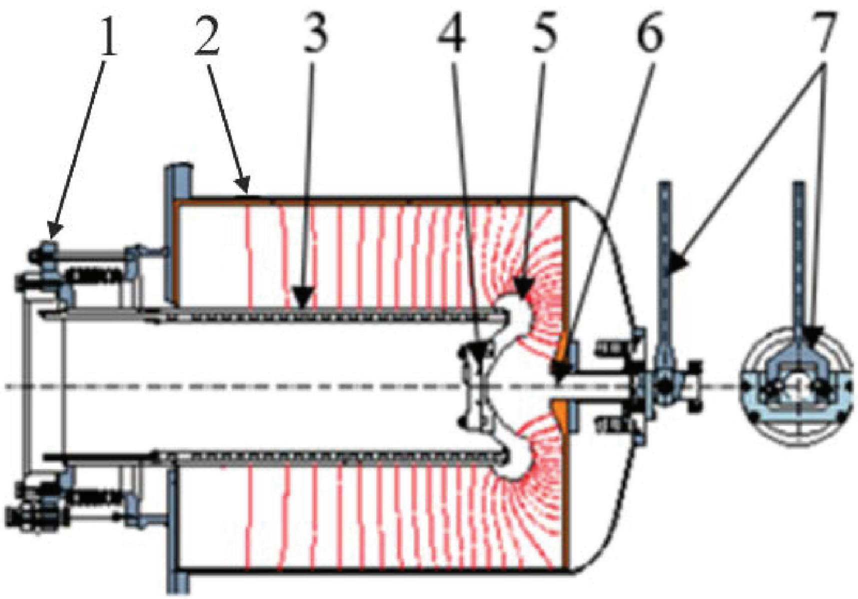


Distribution of electric field longitudinal component in the cavity

Basic accelerator components

RF electron injector

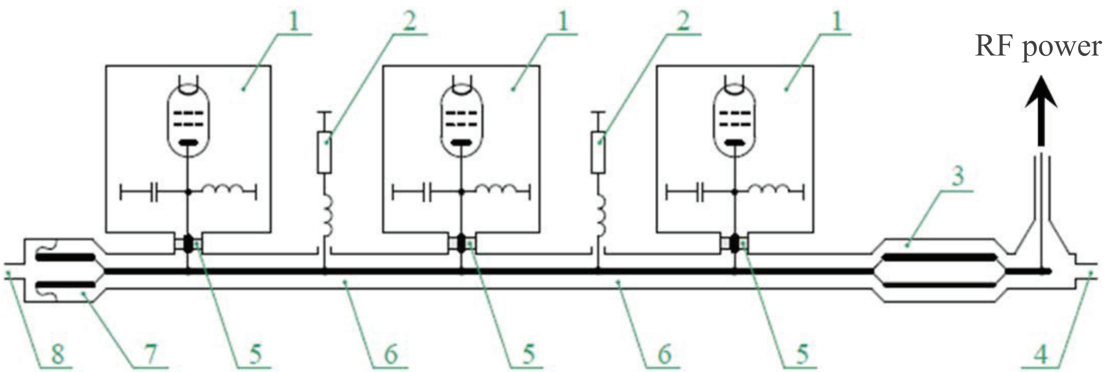
- ❑ Average beam current...................................up to 40 mA
- ❑ Maximum electron energy.............................100 keV
- ❑ Bunch length...~ 1 ns
- ❑ Maximal bunch repetition rate………………...100 MHz



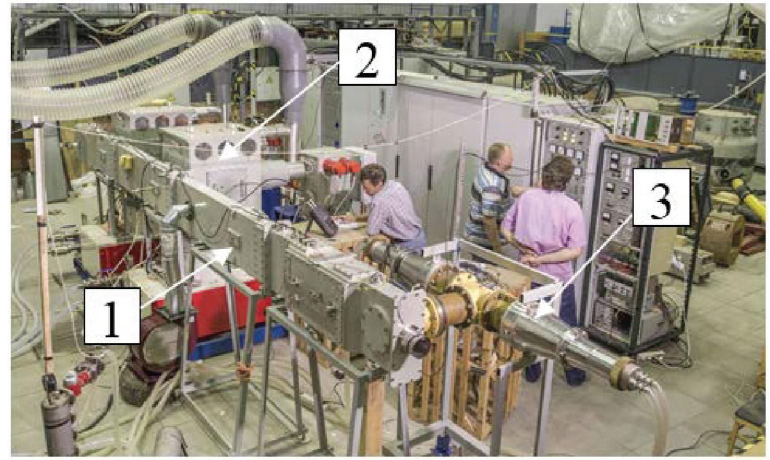
1 – device for electrode-holding and frequency initial tune-up;
2 – cavity body;
3 – cylindrical electrode;
4 – thermo-cathode block;
5 – focusing electrode;
6 – anode;
7 – device of cavity frequency tuning;
8 – RF power input unit

RF power supply system

- RF power supply system is designed to get continuous RF power of 540 kW
- Such system is composed of three typical generators with the output power 180 kW of each of them and RF power summator



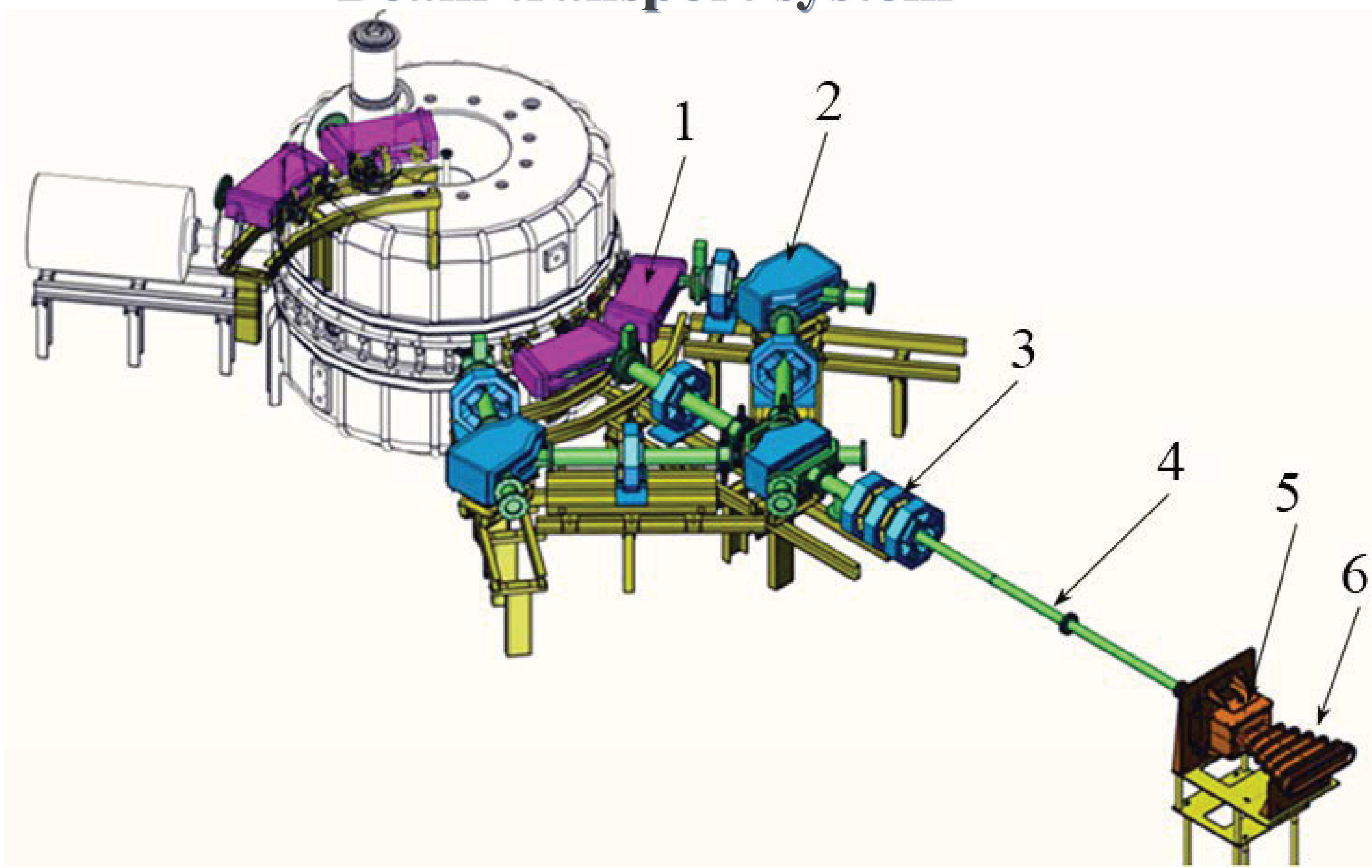
1 – typical generator modules;
2 – resistors to suppress parasitic oscillation;
3 – impedance buffer; 4 – air collector;
5 – communication units of generator modules with summing line;
6 – segments of air TEM –line;
7 – block of frequency tuning; 8 – air inlet



1 – RF power summator;
2 – generator module;
3 – matched load

Basic accelerator components

Beam transport system

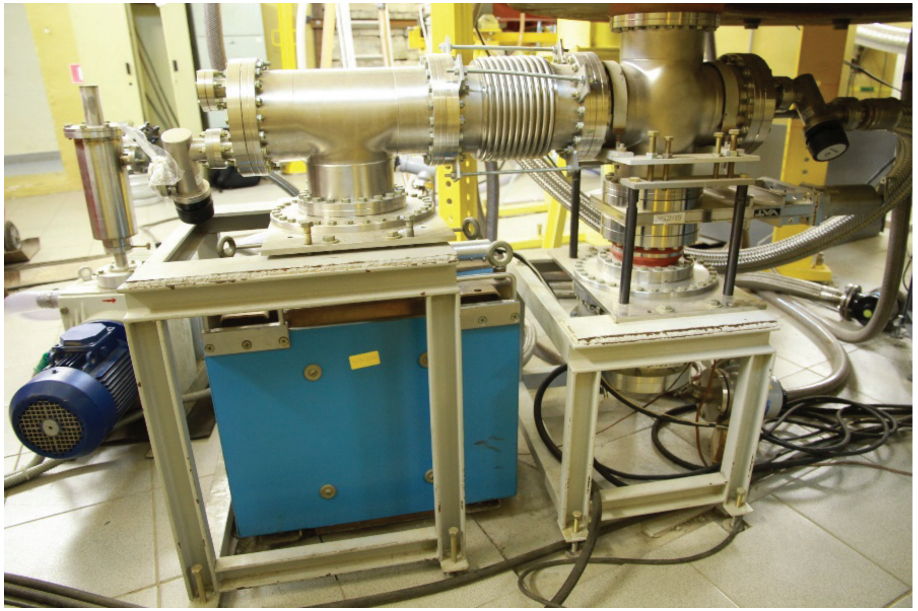


1 – beam recirculation magnets; 2 – beam delivery magnets; 3 – quadrupole lenses;
4 – vacuum beam channel; 5 – scanning magnet; 6 – cone

Basic accelerator components

Technological systems

- Vacuum system providing residual pressure in the interior volume up to 10^{-5} Pa is connected to the cavity
- The installed water cooling and thermal stabilization system is designed to remove heat power excesses up to 400 kW from the accelerator components and to maintain the preset temperature accurate within ± 1°C
- Automatic control system was developed to implement remote control of technological processes

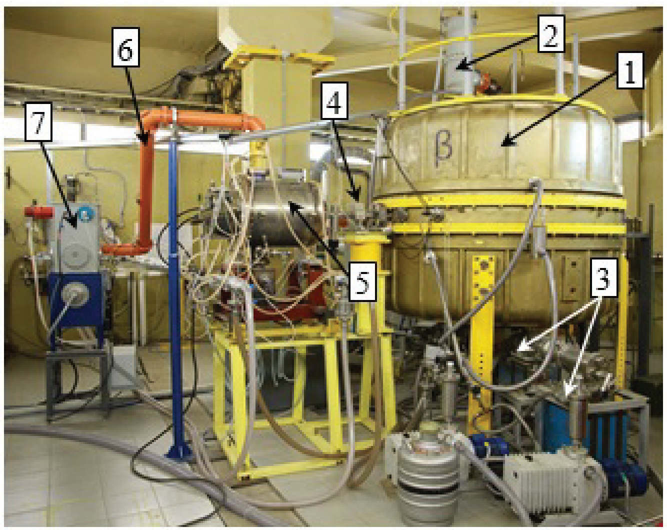


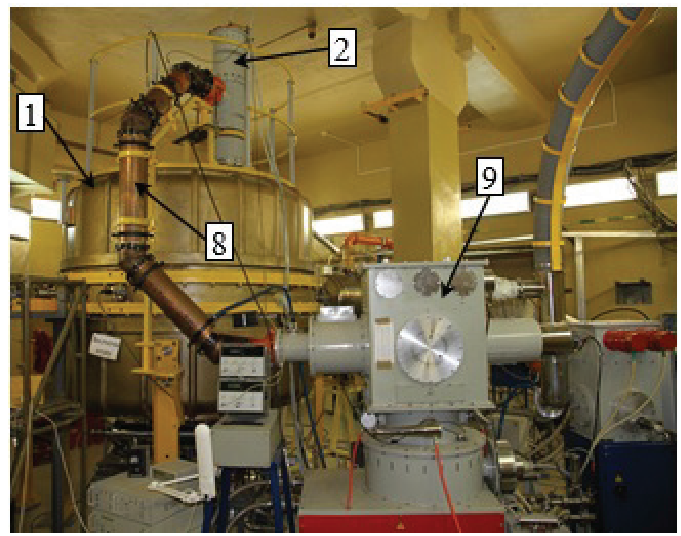
Beam control system

Beam position control system has been developed to minimize beam current losses on the acceleration and drift sections. Such system consists of beam position monitor based on capacitive pickups and magnetic beam-positioning corrector. It allows to determine and correct beam trajectory on-the-fly

Current development status

- ❑ Electric field distribution in accelerating gaps arised in the cavity at RF power of ~ 165 kW is sufficient for electron energy gain up to 1.5 MeV per one pass in the accelerating phase of RF field (beam current – up to 100 μA)
- ❑ Dipole bending magnet has been installed outside of the cavity to provide beam deflection and electron energy gain up to 3 MeV

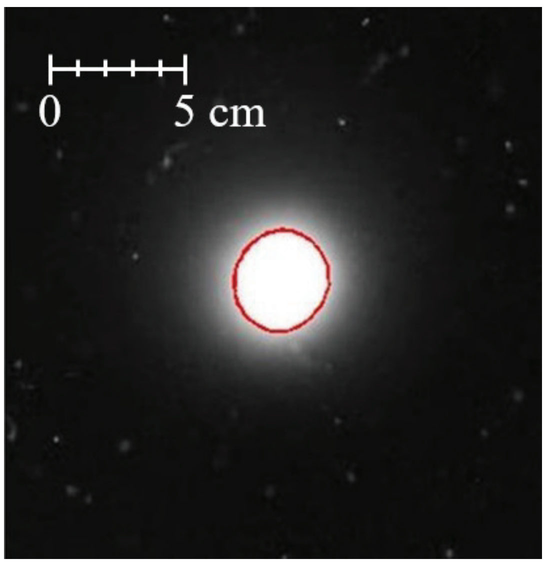




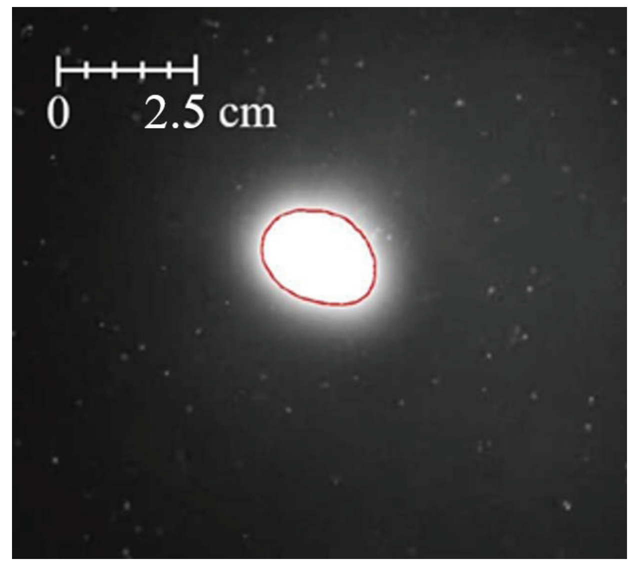
1 – accelerating coaxial cavity; 2 – RF power input unit; 3 – vacuum system; 4 – electron beam injection channel; 5 – RF injector; 6 – RF injector feeder; 7 – RF injector generator; 8 – accelerating cavity feeder; 9 – RF power generator

Experimental results

- Initial research of the accelerator electron beam after one or two passes were performed in the pulsed operation mode of generator module.
- The average beam current varied from 10 to 100 μA
- To evaluate the profile of the beam of accelerated electrons the scintillation screen was installed opposite to the respective output device



(a)

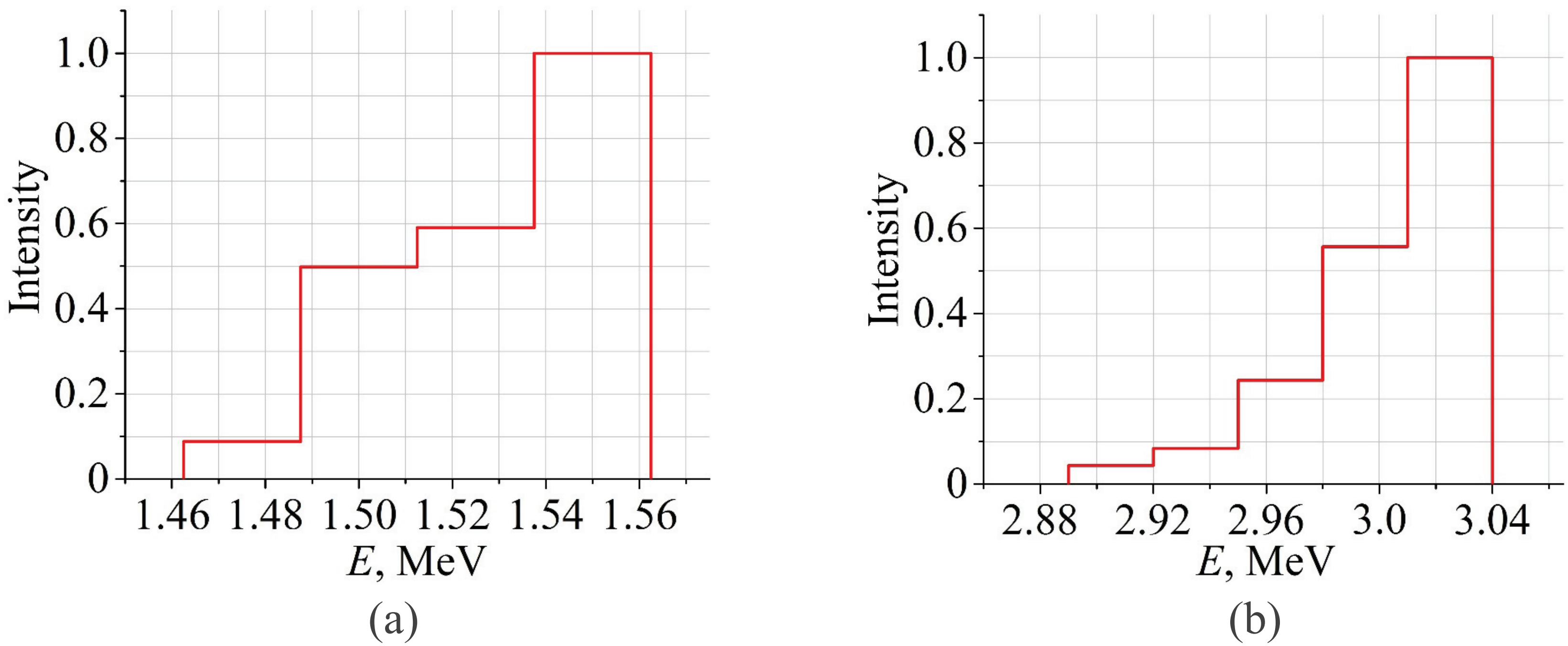


(b)

Scintillator glow pattern: 1.5 MeV (a) and 3 MeV (b)

Electron energy measurement

The energy of accelerated electrons was measured with the help of the method of absorbing filters. The energy spectrum of accelerated electrons was obtained with the help of calculated and experimental distributions of charge on the plates.



Energy spectrum of electrons after one (a) and two (b) passes

- The energy of accelerated electrons after one pass – 1.52 ± 0.05 MeV
- The energy of accelerated electrons after two passes – 3 ± 0.1 MeV

Conclusions

- Compound systems of developing accelerator (RF power supply system, RF injector, vacuum system and cooling system) has been mounted and tested
- The CW accelerator with high power electron beam has been assembled
- To elaborate physical principles of electrons acceleration first investigations were carried out in the pulsed-periodic operation mode on the accelerator. The electron beam current is up to 100 μA.
- The average electron energies were measured using a method of absorbing filters. In case of one-pass mode of accelerator operation the average energy of accelerated electrons is 1.52 MeV. The energy spread is no more than 100 keV. In case of two-pass mode energy is equal to 3 MeV with the energy spread no more than 200 keV
- The experimental beam characteristics correlate well with the calculation results and prove the possibility of five passes through the accelerating cavity to achieve the designed electron energy of 7.5 MeV

Thank you for your attention!