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STATUS REPORT OF DEVELOPMENT OF HIGH POWER BEAM CW ELECTRON ACCELERATOR

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Abstract

The present paper describes the current status of CW resonance electron accelerator design at RFNC-VNIIEF. The range of output electron energy is from 1.5 MeV to 7.5 MeV. The average power of electron beam is up to 300 kW.

Parameters of basic accelerator components (RF power supply system, RF injector, accelerating structure, beam transport system) are presented. The electron acceleration scheme is displayed in this paper.

First experiments were carried out. As a result, 1.5 and 3 MeV electron beams were obtained. The average beam current is up to 100 μA. Derived beam characteristics confirm physical principles of designed accelerator.

INTRODUCTION

The accelerator has been designed for technological process testing required high values of beam power and absorbed dose of electron radiation and bremsstrahlung.

Basic design objectives of the installation are as follows [1]:

- 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.

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 (Fig. 1) [2].

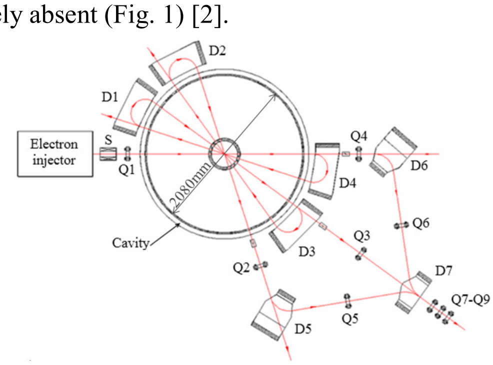

Figure 1: Scheme of the acceleration: → – beam propagation trajectory; D1 – D7 – bending dipole electromagnets; S – focusing solenoid; Q1 – Q9 – quadrupole magnet lenses.

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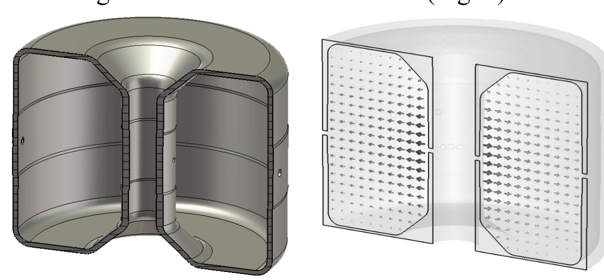
The maximal electron energy of 7.5 MeV is achieved after five passes of electron beam through the accelerating cavity.

Multiple passes of electrons through accelerating gaps is being provided with the help of bending electromagnets arranged outside the cavity (Fig. 1, D1 – D4). With the help of of electromagnets D5 – D7 the accelerated beams with different electron energies is being transported to the output device.

ACCELERATOR COMPOUND SYSTEMS

Accelerating Cavity

The accelerating cavity is a half-wavelength coaxial cavity (a tube surrounding a central conductor, both tubes having coincident axes), shorted at both ends and resonating in metric waves at 100 MHz (Fig. 2).



(a) (b)

Figure 2: 3D-model of the cavity (a) and electric field distribution (b).

RF Power Supply System

To get the average value of beam power equal to 300 kW it is required to provide the accelerating cavity with the 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 [3].

RF power enters the accelerating cavity by a coaxial feeder through RF power input unit. T_1-mode electromagnetic waves are being exited in the cavity with the amplitude of electrical field which provides 1.5 MeV electron energy gain per one pass through the cavity.

Electron Injector

Electron injector is located at the outer wall of the accelerating cavity (Fig. 1). The injector is a grid-controlled thermo-cathode electron RF gun based on a quarter-wavelength coaxial cavity (100 keV, 40 mA, 100 MHz) [4]. Electron bunches enter the accelerating cavity through the injection channel for the subsequent energy gain.

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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 Transport System

Beam transport system consists of two parts: beam recirculation system and beam delivery system (Fig. 3).

In such high power facilities even minimal electron beam current losses leads to serious breakage. For successful beam delivery the transverse emittance should not exceed 50 mm·mrad, while the spectrum width – 0.1 MeV.

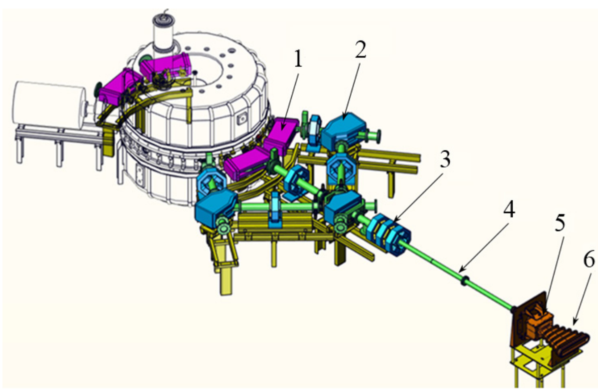

Figure 3: Beam transport system: 1 – beam recirculation magnets; 2 – beam delivery magnets; 3 – quadrupole lenses; 4 – vacuum beam channel; 5 – scanning magnet; 6 – cone.

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 pick-up electrodes and magnetic beam-positioning corrector. It allows to determine and correct beam trajectory on-the-fly.

CURRENT DEVELOPMENT STATUS

Figure 4 presents the current status of the facility, which allows us to try-out basic physical principals of acceleration (up to five passes of the accelerating cavity) at the decreased beam power (up to 10 kW).

In such embodiment the RF power supply is realized by one RF generator module with the power up to 180 kW.

Dipole bending magnet has been installed outside of the cavity to provide beam deflection and electron energy gain up to 3 MeV. The magnet is also intended to shield the beam of the decelerating field phase.

EXPERIMENTAL RESULTS

Initial research of electron beam after one or two passes were performed in the pulsed operation of generator module. Beam current varied from 10 to 100 μA by changing of the electron bunches repetition rate.

To identify availability of the accelerated beam the scintillation screen was installed opposite to the respective output device. The scintillator was forming the image in the visible-light spectrum characterizing the electron distribution in the beam cross-section. Digital video-camera was used to register integral pattern of the scintillation screen glow [5]. Figure 5 presents characteristic images of scintillation screen glow.

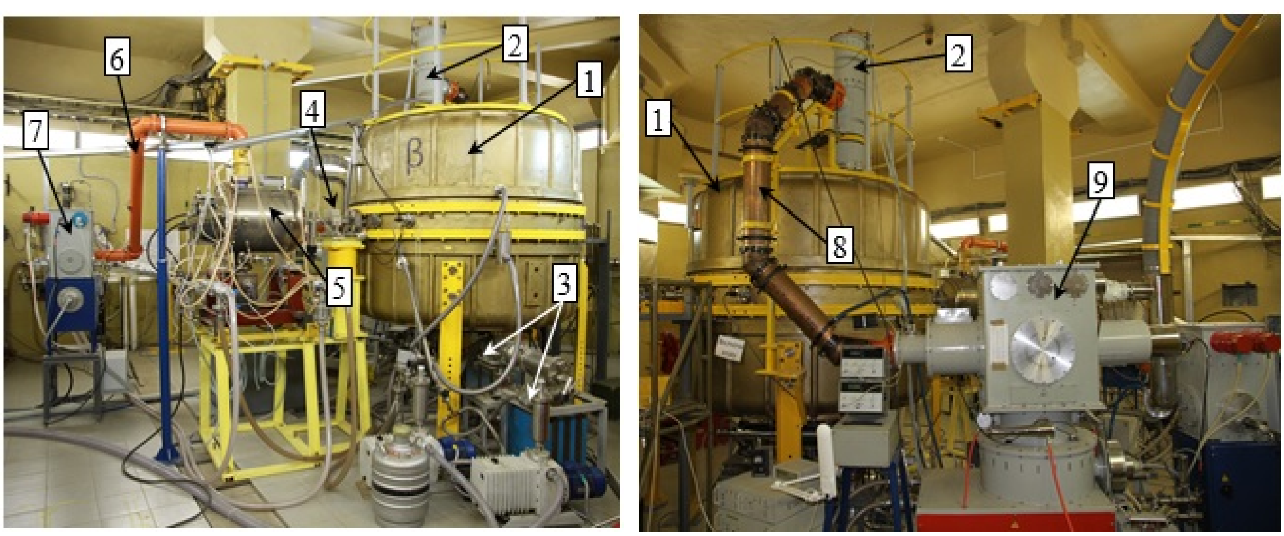

Figure 4: Accelerator external view: 1 – accelerating coaxial cavity; 2 – RF power input unit; 3 – vacuum system; 4 – electron beam injection channel; 5 – RF injector; 6 – RF injector feeder; 7 – generator of RF injector; 8 – accelerating cavity feeder; 9 – RF power generator.

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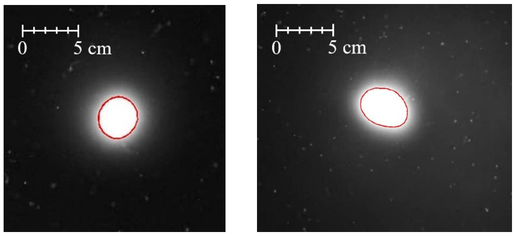
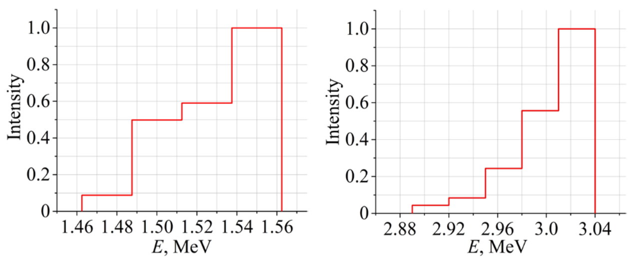


(a) (b)

Figure 5: Scintillator glow pattern: 1.5 MeV (a) and 3 MeV (b).

The energy of accelerated electrons was measured with the help of the method of absorbing filters [6]. The energy spectrum of accelerated electrons was obtained with the help of calculated and experimental distributions of charge on the plates (Fig. 6).



(a) (b)

Figure 6: Energy spectrum of electrons after one (a) and two (b) passes.

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.

CONCLUSION

The current status of the CW resonance electron accelerator development is presented in this paper.

First experiments with 100 µA electron beam were fulfilled on the present accelerator configuration to try-out the physical principles of acceleration.

As a result of the performed investigations the possibility of obtaining the accelerated electrons with the energy of 1.5 and 3 MeV was successfully demonstrated on designed accelerator.

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.

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