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EXPERIMENTAL TESTS OF CW RESONANCE ACCELERATOR WITH 7.5 MeV HIGH INTENSITY ELECTRON BEAM

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Abstract

CW resonance accelerator with high average power electron beam is developed at RFNC-VNIIEF. Electron energy range is varied from 1.5 to 7.5 MeV and average beam current is up to 40 mA.

In this paper we present the results of electron beam dynamics simulation. The operating parameters of RF system, beam optics and bending magnets are determined. These parameters permit to obtain output beam with minimal current losses on each accelerating stage.

As a result of carried out tests 7.5 MeV electron beam was obtained after five passes of accelerating cavity. The electron energy spectrum, average beam current, transverse beam dimensions were determined on each accelerating stage. Common beam current loss is under 10 %.

INTRODUCTION

CW electron accelerator is aimed to obtain beams with the electron energies – 1.5, 3, 4.5, 6 и 7.5 MeV [1]. The accelerator is based on coaxial half-wave cavity (type of oscillations T_1). The electron energy gain up to 1.5 MeV per one pass of the accelerating gap. If it's necessary electrons is returned to the cavity for the subsequent energy gain by bending magnets.

Average beam power at the maximum of energy (7.5 MeV) achieves 300 kW. It becomes possible because of grid-controlled RF gun, which allows to obtain quasicontinuous electron beams with the average current 40 mA and energy 100 keV. RF system of accelerator consists of three independent amplifying cascades and RF power summator. It permits to obtain output RF signal with the average power up to 560 kW at frequency 100 MHz. Main characteristics of CW electron accelerator are shown in Table 1.

Table 1: Characteristics of CW Electron Accelerator

Parameter	Value
Electron energy, MeV	1.5, 3, 4.5, 6, 7.5
Average beam current, mA	40
Operating frequency, MHz	100
Average beam power, kW	300
Average power loss, kW	165
RF system power кВт	560

OPTIMIZATION OF OPERATING MODES

At present accelerator has the ability to product 7.5 MeV electron beams with the average current up to 100 μA. RF system consists of single amplifying cascade with 180 kW of output power. Current scheme of accelerator is shown in Fig. 1.

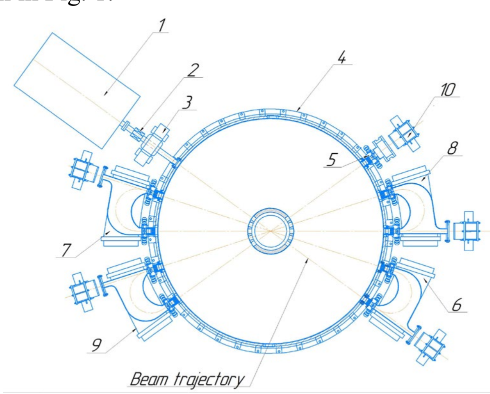

Figure 1: Accelerator scheme (1 – RF injector; 2 – focusing solenoid; 3 – quadrupole lens; 4 – accelerating cavity; 5 – corrector; 6 – 9 – bending magnets; 10 – Faraday cup).

Electron beam dynamics simulation was performed using program code ASTRA (A Space Charge Tracking Algorithm) [2]. Subsequent tests show that optimal beam injection phase into the accelerating cavity vary from - 20 to - 5 degree. Optimal magnetic field in the centre of focusing solenoid (2) is 12 mT. Magnetic quadrupole lens (3) installed in the injection channel is intended to compensate the various effect of transverse components of electric field in the cavity cross-section. Magnetic rigidity of lens is 20 mT [3]. Maximum of electric field inside the cavity is 185 kV/cm.

Calculated electron energy characteristic after each pass of accelerating cavity is shown in Fig. 2. Calculated values of average beam energies and energy spreads is shown in Table 2.

Table 2: Calculated Electron Energies znd Energy Spread

Number of pass	Average energy, MeV	Energy spread, MeV
1	1.5	0.074 (4.9%)
2	3.05	0.098 (3.2%
3	4.51	0.195 (4.3%)
4	6.042	0.311 (5.15%)
5	7.507	0.407 (5.43%)

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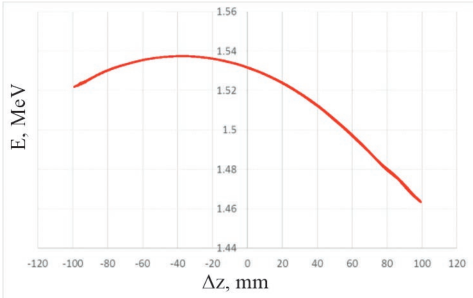
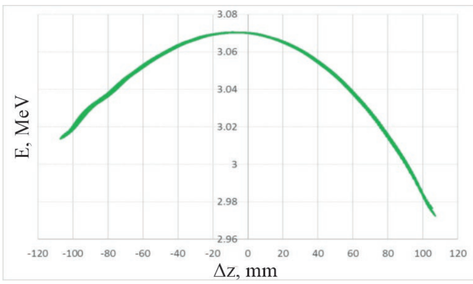
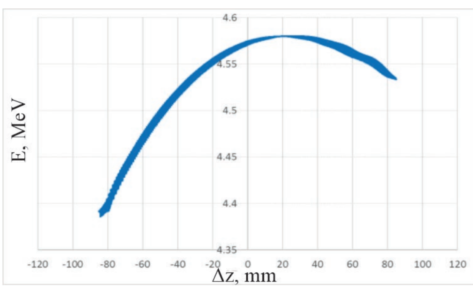


(a)



(b)



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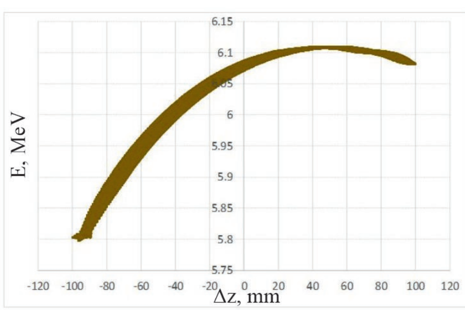
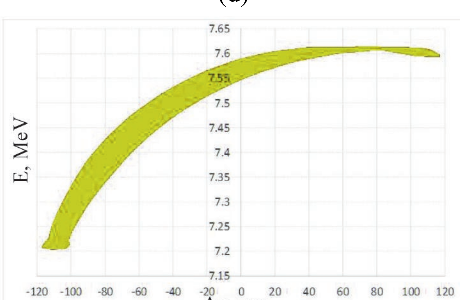


(d)



(e)

Figure 2: Calculated energy distributions in electron bunches after the first (a), second (b), third (c), fourth (d) and fifth (e) accelerating stage.

Calculated magnetic induction values of bending magnets are shown in Table 3.

Table 3: Magnetic Induction Values of Bending Magnets

Number of pass	Magnetic induction, mT
1	-
2	35
3	61
4	95
5	123

EXPERIMENTAL RESULTS

The experiment was aimed to optimization and verification of calculated operating parameters and carried out at the pulse-periodic mode in the interests of safety. The RF pulse duration was 2 ms, the pulse repetition period was 30 ms. The average beam current varied from 10 to 100 μA.

Beam loss was minimized because of calculated data and with a help of correcting magnets which are placed in the input and output of vacuum cameras. Thus, total beam current loss amounts to 8%.

The electron energy spectrum measurement was performed using a method of absorbing filters [4, 5]. The measuring assembly is composed of 23 isolated from each other aluminum plates with air gap between them (Fig. 3). The thickness of plates varied from 0.15 mm for 1.5 MeV electrons to 1 mm for 7.5 MeV electrons.

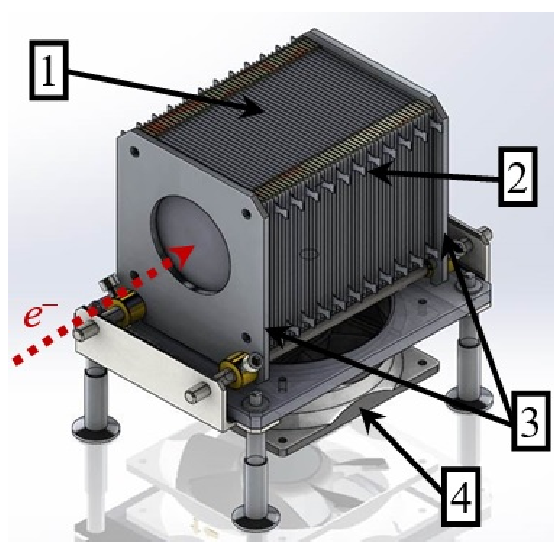


Figure 3: Measuring assembly: 1 – aluminum plates; 2 – current pickups; 3 – retention flanges; 4 – fan.

During experiment beam induced current from each plate was measured, while other plates were grounded. The electric scheme of plate connection is shown in Fig. 4.

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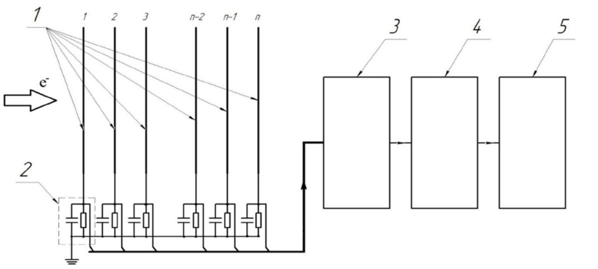

Figure 4: Electric scheme of plate connection in energy detector: 1 – aluminum plates; 2 – smoothing-integrating RC-filter; 3 – analog-digital converter; 4 – controller ; 5 – PC with software; (1…n) – number of absorbing plate.

Using calculated and experimental charge distributions on absorbing plates the electron energy spectrums after each accelerating stage were reconstructed (Fig. 5).

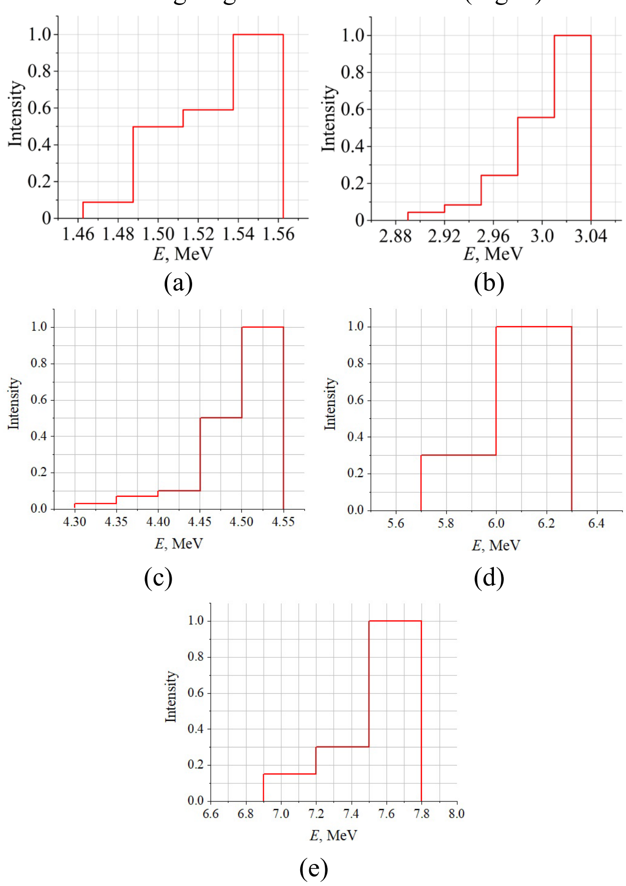

Figure 5: Reconstructed electron energy spectrum after one (a), two (b), three (c), four (d) and five (e) passes of accelerating cavity

Measured electron energy characteristics on each accelerating stage are shown in Table 4.

Table 4: Measured Electron Energies and Energy Spread

Number of pass	Average energy, MeV	Energy spread, MeV
1	1.5	0.100
2	3.05	0.150
3	4.51	0.200
4	6.042	0.310
5	7.5	0.4

CONCLUSION

The simulation series aimed to optimization of accelerator operating parameters were performed. Optimal beam injection phase into accelerating cavity, injection channel parameters, magnetic induction values in bending magnets were precisely determined.

The electron beam was experimentally obtained after each of five passes of accelerating cavity. Beam current loss is under 10%.

Measured and calculated electron energy characteristics are found in good correlation.

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