BEAM PARAMETERS OF A TWO-SECTIONAL ELECTRON LINAC WITH THE INJECTOR BASED ON A RESONANCE SYSTEM WITH EVANESCENT OSCILLATIONS

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Abstract

The S-band electron linac has been designed at NSC KIPT to cover an energy range from 30 to about of 100 MeV. The linac consists of a couple of the four-meter long piecewise homogeneous accelerating sections. Each section is supplied with RF power from a separate klystron. The peculiarity of the linac is using of the injector based on evanescent oscillations. The report presents both simulation results of self-consistent particle dynamics in the linac and results of measurement of beam parameters.

INTRODUCTION

There is the growing interest to researches of photonuclear reactions on lights nuclei. For conducting of researches, in particular, for refinement of cross-sections of such reactions, the flows of photons are needed with the regulated value of maximal energy. The flows of such photons can be got by the linear accelerators of electrons. The decision to create such research linac was accepted at NSC KIPT in 2002. Description of the linac is given in [1]. The linac consists of an injector, two piece-wise homogeneous accelerating sections and a beam transport system. The injector consists of the 25 keV diode electron gun and the buncher on the basis of the resonance system with evanescent oscillations [2]. The linac is commissioning now and the first results of beam characteristic measurement are obtained. Simulation results of self-consistent particle dynamics in the linac obtained by using the PARMELA code [3] and a technique [4] are compared with the experimental results. The technique allows to simulate particle motion in a linac that includes beam transport elements and both standing wave and traveling wave resonance structures.

INJECTOR

The chain of five coupled E_{010} cavities is used as the resonant system of the injector. The cavities are coupled through the central apertures for beam passing. For realization of the required distributing of the on-axis field, the injector operating frequency, which is close to the eigen frequency of the last cavity, was chosen higher than that of «π» mode of homogeneous part of the resonance system (cavities two through four). For such situation the phase advance of the field per a cell remains equal π. Fig. 1 shows comparison of the calculation and measured distribution of the field on the axis of the injector. One can see the good match of calculated and measured data.

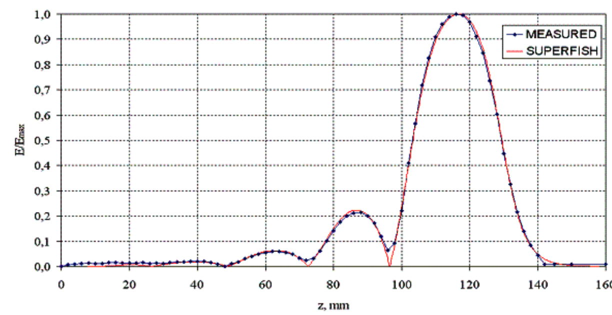

Figure 1: Distribution of the electrical field amplitude along the axis.

The dispenser oxide cathode with a radius of 2.5 mm and the radius of curvature of 7.5 mm is used in the electron gun of the injector. The optical system of the gun was designed with the EGUN code [5]. The final choice of electrode shapes was chosen taking into account the beam dynamics in the injector, because calculations showed that both beam size in a waist and position of the waist influence the bunching due to space charge forces. Simulation of particle dynamics in the injector was executed with the PARMELA code. To study the self-consistent task, the technique [4] was used. Example of simulation results for a case, when duration of current pulse was longer then that of the RF pulse is shown in Fig. 2.

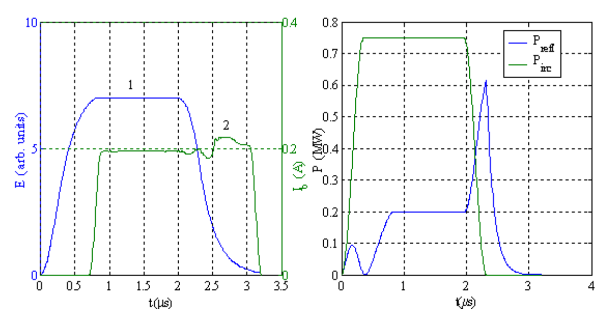

Figure 2: On-axis field (1) and output current (2) (on the left), pulses of incident and reflected powers in the RF feeder of the injector (on the right).

The experimental study of the injector with a beam was carried out on the special stand, which provided the RF power supply to the resonance system, high voltage and filament supplies to the electron gun as well as measuring of beam characteristics. Fig. 3 shows oscillogram of current pulse on the output of the injector for the similar case represented in Fig. 2. One can see the good correspondence of peculiar behavior of current in time.

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Measured dependence of beam emittance ε, beam energy W and energy spread ΔW/W on feeding RF power is shown in Fig. 4. Beam emittance was evaluated from a set of full width on a half of magnitude of beam transverse spot size obtained under quadruple scan. So hereinafter the measured emittance are noted with 'FWHM'. Energy spread was determined with 90° bending magnet. The measured and expected parameters of the injector are resulted in Table 1.

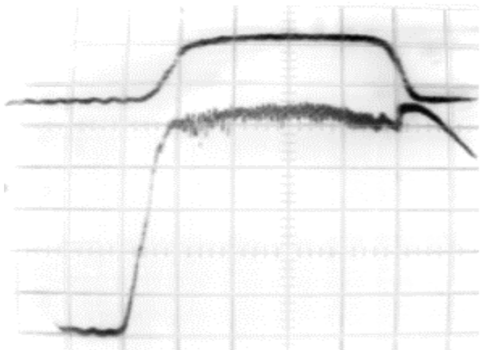

Figure 3: Waveform of signal from the control loop of the injector resonance system and current of the injector (38 mA/div, horizontal scale 0.5 μs/div).

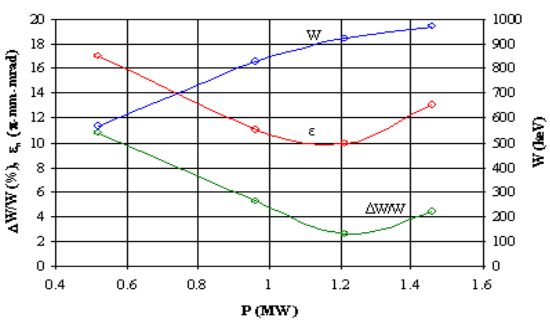

Figure 4: Dependence of beam characteristics on feeding RF power.

Table 1: Specifications of the injector.

Parameter	Measured	Expected
Gun high voltage, kV	-25	-25
Cathode radius, mm	2.5	2.5
Beam waist, mm	1.4	2.2
Gun current, A	0.22	0.22
Operating frequency, MHz	2797.15	2797.15
Unloaded quality factor	11000	12298
Shunt impedance, MOhm/m	15	18.6
Coupling with the feeder	4.6	–
Incident power, MW	1.2±0.1	0.75
Injector current, A	0.16	0.191
$\varepsilon_{n\,x,y}$, π·mm·mrad	10 (FWHM)	15 (rms, 1σ)
Δφ, degrees (70% of particles)	–	22
W, keV	900	850
ΔW/W, % (FWHM)	2.6	2.3

Measured parameters of the beam are consistent with simulated ones. Discrepancy in values of measured and expected incident powers is due to some uncertainty of measured power on the one hand and some uncertainty of measured shunt impedance on the other hand. For bead-pull measurements of the on-axis field pattern with large difference in field amplitude along the axis the bead should be large enough. It tends to overestimation of the shunt impedance because of field integration over the bead.

ACCELERATING SECTIONS

The choice of a linac structure has been carried out by using simulation results of self-consistent transient dynamics of particles in traveling wave accelerating sections that were obtained with method [6]. Taking into account the results of simulations and available resources, we stopped our choice on a linac structure that includes the two four-meter long «Kharkov-85» sections [7]. The sections are piece-wise homogeneous disc loaded waveguides consisting of four pieces with a constant impedance. Each piece matches with subsequent one through five transitional cells. Total amount of cells per the section is 162, phase advance per a cell is 90° and operating frequency is 2797.15 MHz. Electrodynamic characteristics of these sections were calculated both by interpolation of data [8] and using the method [9]. Both ways gave the similar results. Calculated values of series impedance of the first, second, third and fourth pieces of the sections are equal to 1082, 1430, 1943 and 2930 Ohm/cm^2 accordingly. The values of filling time and attenuation of the whole sections are 0.92 μs and 0.68 Neper correspondently. Because the sections were used as a part of the LUE-2000 linac a long time ago [7], before their using in the designed linac, their electrodynamic characteristics were tested. After obtaining the refined data, simulation of self-consistent beam dynamics was performed with technique [4]. Between the injector and the first accelerating section adjustable collimator is installed to cover a wide range of accelerated currents preserving conditions of bunching. Accordingly, under the simulations needed output current of the linac was obtaining by beam collimations. Plots of mean particle energy W, energy spread ΔW/W and phase extent Δφ of bunches against time within a current pulse duration are shown in Fig. 5. Accelerated current was 63 mA, Powers of RF supply of the injector and each accelerating section were 1.2 MW and 16 MW respectively. RF pulses were flat-toped. One can see the change of the mean energy by 3 MeV during the pulse due to the beam loading at that accelerated current. For diminishing the change, the HV pulse of the klystron feeding the second section was distorted to have some rise of output power to the end of RF pulse. The measured spectrum of a beam at that current is shown in Fig. 6. It is possible to see that time and value of transitional process are some diminished.

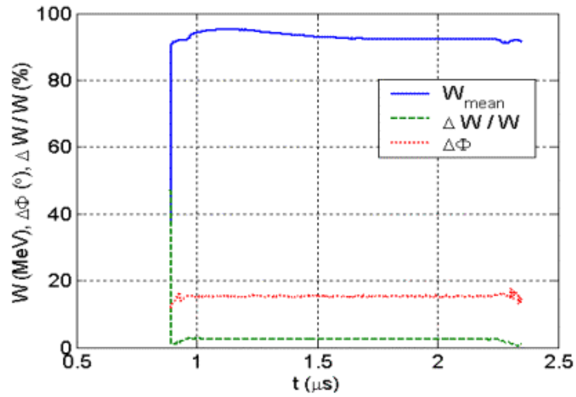

Figure 5: Simulated beam characteristics.

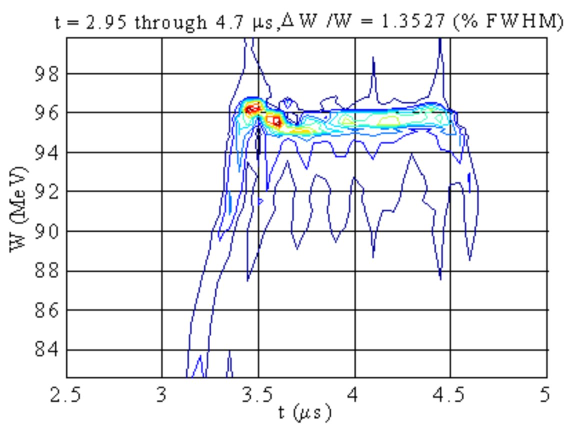

Figure 6: Contour plot of measured energy spectrum.

At the first test of the linac transversal emittance of the beam was measured by the quadruple scan method. Fig. 7 shows the dependence of horizontal profile width of a beam on the quadruple current. Similar dependence was measured for the vertical profile. Data processing gave the values of normalized emittance that are listed in Table 2. There are other measured and calculated parameters of a beam at the exit of the linac enumerated in Table 2 for comparison.

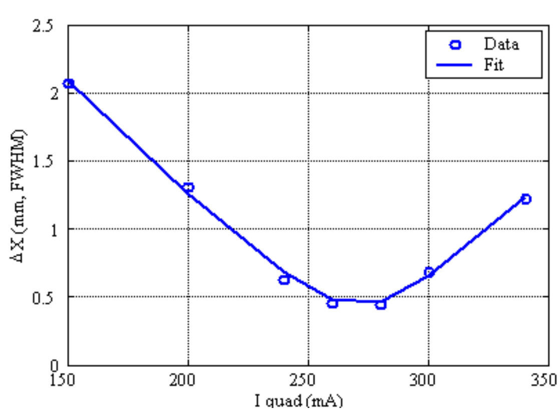

Figure 7: Results of the quadruple scan.

The measured values of transversal beam emittance are low enough as compared to that of linacs with the traditional type of injectors. Therewith comparison of the simulated results of particle dynamics with the first experimental data on beam characteristics shows reserve for the beam improvement. In particular it concerns with transversal beam emittance. Ongoing researches at the linac are aimed on development of the reliable scheme of computer control of beam energy as well as on checkout of equipment and improvement of beam parameters.

Table 2: Beam parameters at the linac exit.

Parameter	Expected	Measured
Pulsed current, мA	63	63 (30 – 120)
W, MeV	95	95 (50 – 100)
ΔW/W, % (FWHM)	1.4	1.5
Δφ, degrees, (70% of particles)	15	
Δx, Δy at the target (FWHM), mm	0.1, 0.1	0.44, 0.68
$\varepsilon_{n\ x,\ y}$, π·mm·mrad	6, 6 (rms, 1σ)	63, 72 (FWHM)

CONCLUSION

Two-sectional electron linac with beam energy and current 100 MeV and 120 mA respectively is developed and constructed at NSC KIPT. Relatively low value of transversal emittance allows to obtain high beam density on a target. We intend to conduct intensive researches of bunch forming to diminish the transversal emittance to the value predicted by calculations. At the same time it is planed to carry out researches of photonuclear reactions on lights nuclei in the near future.

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