BEAM PARAMETERS OF AN S-BAND ELECTRON LINAC WITH BEAM ENERGY OF 30…100 MeV

A.N. Dovbnya, M.I. Aizatsky, V.N. Boriskin, I.V. Khodak, V.A. Kushnir, V.V. Mytrochenko, A.N. Opanasenko, S.A. Perezhogin, L.V. Reprintsev, A.N. Savchenko, D.L. Stepin, V.I. Tatanov, V.F. Zhiglo
NSC KIPT, Kharkov, Ukraine
E-mail: mitvic@kipt.kharkov.ua

An S-band electron linac has been erected at the NSC KIPT to cover an energy range from 30 to about of 100 MeV. The linac consists of a couple of four-meter long piecewise homogeneous accelerating sections. Each section is supplied with RF power from a separate klystron KIU-12AM. The feature of the linac is in the use of an injector based on evanescent oscillations. Results of beam parameters' measurement of at the linac exit are presented.

PACS: 41.75.Ht, 25.20.-x

1. INTRODUCTION

Studies into photonuclear reactions on light nuclei require information on a photon flux with fixed value of maximum energy. This photon flux can be obtained by an electron linac. The research linac that will be used for the above-mentioned purpose has been designed and constructed at the NSC KIPT. The linac can be used also for investigations into numerous physical phenomena connected with interaction of relativistic electron beams with electrodynamic systems and condensed media. Description of the linac is given in Ref. [1]. The linac consists of an injector, two piece-wise homogeneous accelerating sections and beam transport system. The injector consists of a 25 keV diode electron gun and buncher on a basis of a resonance system with evanescent oscillations [2]. The linac is now commissioning and the first results of beam measurements have been obtained. Simulation results of self-consistent particle dynamics in the linac obtained by using the PARMELA code [3] and technique [4] are compared with the experimental results.

2. SIMULATIONS

The chain of five coupled E_{010} cavities is used as a resonant system of the injector. The cavities are coupled through the central apertures for beam passing. For realization of the required on-axis field distribution, the injector operating frequency close to the eigenfrequency of the last cavity was chosen higher than frequency of the «π»-mode of a homogeneous part of the resonance system (from the second to fourth cavities). For such situation the phase advance of the field per cell remains equal π, while field amplitude drops rapidly from the fifth cell to the first one.

The dispenser oxide cathode with a radius of 2.5 mm and curvature radius 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 made taking into account the beam dynamics in the injector because the calculations showed that both the beam size in a waist and the waist position influence the bunching due to the space charge forces.

Simulation of particle dynamics in the injector was performed 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 than that of the RF pulse is shown in Fig.1.

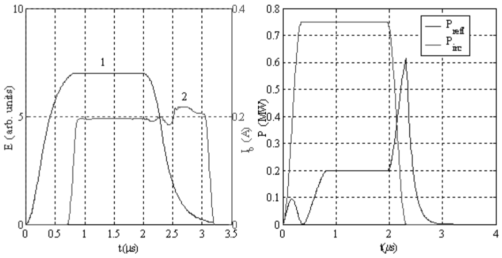

Fig.1. On-axis field (1) and output current (2) (on the left), pulses of incident and reflected powers in the RF feeder of the injector (on the right)

The choice of a linac structure has been made by using simulation results of self-consistent transient dynamics of particles in traveling wave accelerating sections obtained with method [6]. Taking into account simulation results and available resources, we stopped our choice on a linac structure that includes 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 cell number per section is 162, phase advance is 90° per cell, and operating frequency is 2797.15 MHz. Electrodynamic characteristics of these sections were calculated both by data interpolation [8] and using the method from Ref. [9]. Both methods 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 for filling time and attenuation of the whole sections are 0.92 μs and 0.68 Neper, correspondently. Previously, these sections had been used as a part of the LUE-2000 linac [7]. Before their usage in the designed linac, the electrodynamic characteristics of these sections were tested. Having obtained the refined data, numerical simulation of self-consistent beam dynamics was performed with technique [4]. Between the injector and the first accelerating section an adjustable collimator is installed to cover a wide range of accelerated currents preserving conditions for bunching. Thus, a required output current of the linac was obtained in simulations by using beam collimations. Plots of mean particle energy W, energy spread ΔW/W and phase extent Δφ of bunches versus time within a current pulse duration are shown in Fig.3. Accelerated current was 63 mA, RF power 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 the accelerated current.

3. EXPERIMENTAL STUDY OF BEAM CHARACTERISTICS

The experimental study of the injector with a beam was carried out on the special stand that provides the RF power supply to the resonance system, high voltage and filament supplies to the electron gun as well as beam characteristics' measurements.

Measured dependence of a beam emittance ε, beam energy, and energy spread on feeding RF power is shown in Fig.2. Beam emittance was evaluated from a set of full width on a half of magnitude of beam transverse spot size obtained under quadrupole scan. Energy spread was determined by 90° bending magnet. The measured and expected parameters of the injector are presented in Table 1.

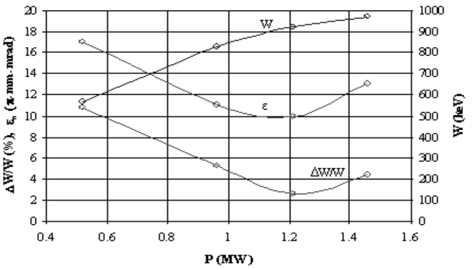

Fig.2. Dependence of beam characteristics on feeding RF power

***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	15
Δφ, ° (70% of particles)	–	22
W, keV	900	850
ΔW/W, % (FWHM)	2.6	2.3

Measured beam parameters are consistent with simulated ones. Discrepancy in measured and expected incident power is due to some uncertainty in power measurement, on the one hand, and some uncertainty of shunt impedance measured, 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 results in overestimation of the shunt impedance because of field integration over the bead.

After the injector had been studied, it was joined with the accelerating sections (see Fig.3).

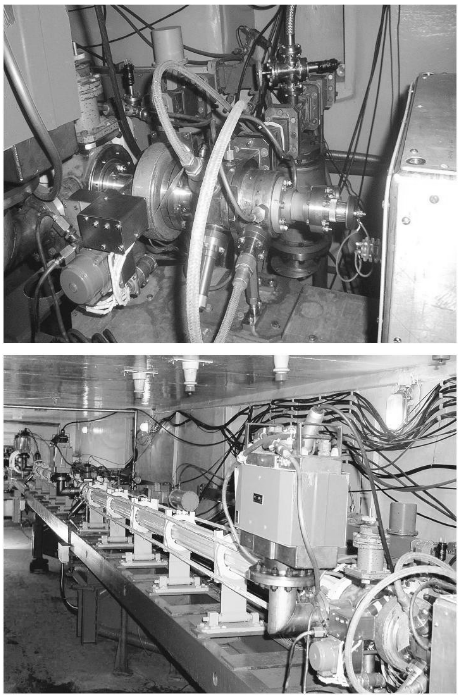

Fig.3. The injector (top) joined wit the accelerating sections (bottom)

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 beam spectrum at the current is shown in Fig.5. One can clearly notice that time and value of transitional process is diminished slightly.

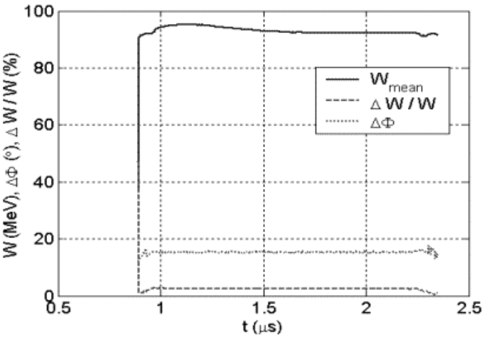

Fig.4. Simulated beam characteristics

At the first test of the linac the beam transversal emittance was measured by the quadrupole scan method. Fig.6 shows the dependence of a horizontal beam profile width on a quadrupole 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 beam parameters at the exit of the linac enumerated in Table 2 for comparison.

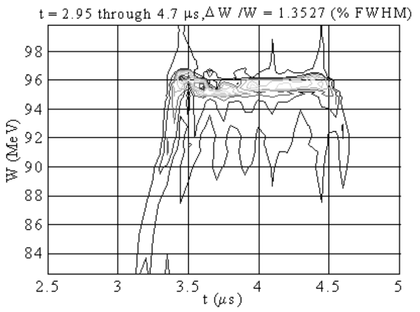

Fig.5. Contour plot of measured energy spectrum

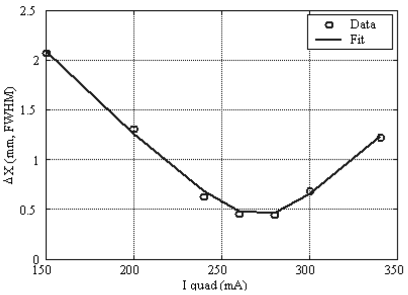

Fig.6. Results of the quadrupole scan

Table 2. *Beam parameters at the linac exit*

Parameter	Expected	Measured
Pulsed current, мА	63	30…120
W, MeV	95	50…00
ΔW/W, % (FWHM)	1.4	1.5
Δφ, ° (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	63, 72

The measured values of the transversal beam emittance are much lower as compared to that of linacs with conventional injector type. Therewith, the 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 the transversal beam emittance. Ongoing research activities at the linac have an ultimate goal in development of a reliable scheme for computer control of beam energy as well as in equipment checkout and beam parameters improvement.

CONCLUSION

Two-sectional electron linac with beam energy of 100 MeV and current of 120 mA has been developed and constructed at the NSC KIPT. Relatively low value of the transversal beam emittance allows obtaining 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 planned to carry out researches of photonuclear reactions on lights nuclei in the nearest future.

REFERENSES

1. K.I. Antipov, M.I. Aizatsky, Yu.I. Akchurin et al. // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 2004, №5, p.135.
2. M.I. Aizatsky, E.Z. Biller, N.G. Golovko et al. // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 2004, №1(42), p.60.
3. L.M. Young, *“PARMELA”*. LA-UR-96-1835. Los Alamos, 1996.
4. A.N. Opanasenko, V.V. Mitrochenko. *Simulation Technique for Study of Transient Self-consistent Beam Dynamics in RF Linacs.* Proc. of EPAC 2004, Lucerne. 2004, p.2792.
5. W.B. Herrmannsfeldt. *EGUN: Electron Optics Program.* SLAC-PUB-6729. Stanford Linear Accelerator Center, 1994.
6. M.I. Aizatsky. *Nonstationary Model for Beam Dynamic Simulation in Multisectional Accelerators* // Proc. of EPAC 98, Stockholm. 1998, p.1159.
7. E.Z. Biller, A.N. Dovbhya, V.A. Kushnir et al. // *Part. Accel.* 1990, №.27, p.119.
8. O.A. Valdner, N.P Sobenin, B.V. Zverev, I.S. Schedrin. *Disk loaded waveguides*: *Handbook.* M.: “Energoizdat”, 1991 (in Russian).
9. G.A. Loew, R.H. Miller, R.A. Early, K.L. Bane // *IEEE Trans. Nucl. Sci.* 1979, NS-26, p.3701.

ПАРАМЕТРЫ ПУЧКА ЛИНЕЙНОГО УСКОРИТЕЛЯ ЭЛЕКТРОНОВ 10–см ДИАПАЗОНА НА ЭНЕРГИЮ 30…100 МэВ

А.Н. Довбня, Н.И. Айзацкий, В.Н. Борискин, И.В. Ходак, В.А. Кушнир, В.В. Митроченко, А.Н. Опанасенко, С.А. Пережогин, Л.В. Репринцев, А.Н. Савченко, Д.Л. Степин, В.И. Татанов, В.Ф. Жигло

В ННЦ ХФТИ создан линейный ускоритель электронов 10-см диапазона на энергию 30…100 МэВ. Ускоритель состоит из двух кусочно-однородных четырехметровых ускоряющих секций. СВЧ-питание каждой секции осуществляется от клистрона КИУ-12АМ. Особенностью линейного ускорителя является использование инжектора, основанного на нераспространяющихся колебаниях. Приведены результаты измерения параметров пучка на выходе ускорителя.

ПАРАМЕТРИ ПУЧКА ЛІНІЙНОГО ПРИСКОРЮВАЧА ЕЛЕКТРОНІВ 10-см ДІАПАЗОНУ З ЕНЕГІЄЮ 30…100 МеВ

А.М. Довбня, М.І. Айзацький, В.М. Борискін, І.В. Ходак, В.А. Кушнір, В.В. Митроченко, А.М. Опанасенко, С.О. Пережогін, Л.В. Репринцев, А.М. Савченко, Д.Л. Стьопін, В.І. Татанов, В.Ф. Жигло

Наведені результати вимірювання параметрів пучка на виході створеного в ННЦ ХФТІ прискорювача електронів. Прискорювач складається з двох кусково-однорідних чотирьохметрових прискорювальних

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2006. № 2.
Series: Nuclear Physics Investigations (46), p.11-13.

секцій. Живлення кожної секції здійснюється від клістрона КІУ-12АМ. Особливістю прискорювача є застосування інжектора, заснованого на коливаннях, що не розповсюджуються.