THE ELECTRON INJECTOR FOR LINAC OF THE "NESTOR" STORAGE RING

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Results of the bunching system design and electron motion simulation in the compact S – band injector are presented. The injector consists of the low-voltage diode electron gun and bunching system based on the resonant system with the evanescent oscillations. The amplitude of RF electrical field grows along the axis of the bunching system. The resonance system optimization has been carried out that allows obtaining of the electron bunch with the phase length less than 10° and energy spread less than 5% (for 70% particles) at the injector exit.

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1. INTRODUCTION

An increase of the electric field along the axis of a resonant system of an injector allows improving of short bunches formation at comparatively small energy spread [1-3]. There is suggested an injector [4] in which to create an increasing field along the axis of the resonant system, a section of periodic disc-loaded waveguide excited in the stop-band was applied. The choice of such a resonant system is based on system easiness in tuning for obtaining the increasing field distribution. The more detailed particles dynamic analysis has shown that the choice of identical cavity lengths in the middle part of the resonant system is not optimal for the bunching process.

When creating the linac for the storage ring "NESTOR" [5] the purpose was to obtain the minimum energy spectrum width ($\Delta W/W<1\%$) at the linac exit. To decrease the energy spread at the injector exit it is necessary to decrease the bunch phase length at the linac input. It is possible to achieve such beam parameters at the phase length of the electron beam at the injector exit $\Delta\varphi<10°$.

The purpose of this research is to develop the electron injector providing the minimum phase bunch size at the injector exit at the energy spread ($\Delta W/W<5\%$) and normalized emittance ($\varepsilon_{n\,rms}<15$ mm·mrad). In the base of the injector being developed there is the injector developed and produced for the linac at the energy up to 100 MeV [6].

2. BUNCHING SYSTEM

To calculate the electrodynamics characteristics of the resonant system the SUPERFISH group of codes has been used [7]. The simulation of particle dynamics in the diode gun and in the bunching resonant system has been carried out with the use of the EGUN code [8] and the PARMELA code [9]. To achieve the phase bunch length at the bunching system exit $\Delta\varphi<10°$ there was applied a procedure of resonant system optimization represented in Ref. [10]. The main point of the optimization was to select the field distribution on the system axis that provides minimum bunches phase length. The required field distribution is achieved by the variation of the field amplitudes in each of the resonators and their appropriate lengths change.

Based upon the optimization procedure represented, the injector resonant system has been calculated and developed. In Fig.1 the optimized resonant system of the injector is shown.

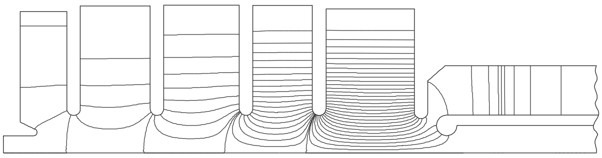

Fig. 1. Resonant system geometry and space field distribution

Besides the resonator sizes changing, the injector construction has been modified as well. In the initial injector construction the RF power is supplied by the rectangular waveguide through the coupling window that resulted in the radial inhomogeneous field. To eliminate that disadvantage there was suggested to supply the RF power into the resonant system through the coaxial waveguide.

As stated before [6], while operating the injector there was observed an instability. We explained that as the poliphase secondary emission discharge in the first resonator. To eliminate that phenomenon the geometry of the first resonator has been changed (see Fig.1).

By the simulation results the main electrodynamics characteristics of the bunching system have been defined (the results are presented in Table 1).

Table 1. *Electrodynamics characteristics of the bunching system*

Parameter	Value
Operating frequency f_O, MHz	2797.15
Quality factor	12354
Shunt impedance, MOhm/m	18.4
Power losses in walls, kW	558
Maximum field on the axis, MV/m	39.4
The coupling coefficient of the feeder with the resonance system	3.8

The coupling coefficient of the feeder with the resonance system has been chosen according to the duration of the transient processes in the resonant system. The resulting optimized field distribution on the resonant system axis is presented in Fig.2.

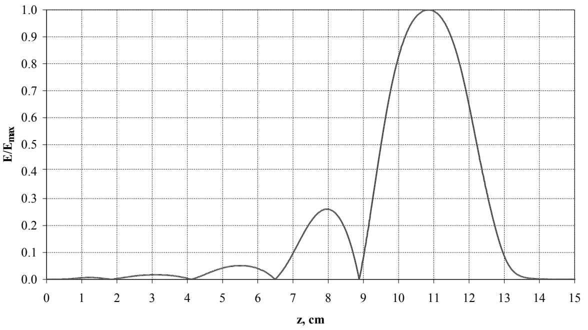

Fig.2. Distribution of on-axis field after the optimization

To ascertain the influence of the operating frequency change ($f=f_O\pm0.2$ MHz) onto the field distribution in the resonant system and onto the beam characteristics at the injector exit, the appropriate calculations have been performed for $\Delta f=f_O\pm f$. In Table 2 there are shown the values of the electric field strength relative variation towards the field in the fifth resonator on the resonant system axis for each resonator according to the operating frequency change.

***Table 2**. The electric field relative variation on the system axis in each resonator at the operating frequency change*

Resonator's number	1	2	3	4	5
ΔE/E (-0.2 MHz), %	-1.9	-1.6	-0.9	-0.6	0
ΔE/E (+0.2 MHz), %	1.9	1.5	0.9	0.6	0

As it is seen from the table, the frequency change within rather large limits does not result into the substantial field redistribution in the resonant system.

3. RESULTS OF BEAM DYNAMICS SIMULATION IN THE INJECTOR

The simulation has been carried out for an electron beam with the initial energy 25 keV and current 245 mA, with taking into account the space charge force. To take space charge forces correctly, the input beam was represented by a bunch with length of $5\beta\lambda$, where β is initial relative speed of particles, λ is the operating wavelength.

To reduce the influence of space charge on a transversal emittance, the electron gun should be placed as close as possible to the bunching system. Therefore, in the developed buncher the inlet opening for beam injection is an anode of the gun. The computational parameters of the gun and beam characteristic without taking into account the influence of a RF field are listed in Table 3. The calculations have been carried out with the code EGUN [8].

As a result of electron beam dynamics simulations, the beam characteristics at the injector exit have been defined (see Table 4 and Fig.3). In Table 4 there also are presented the electron bean characteristics at the injector exit at the change of the operating frequency within ±0.2 MHz. The beam characteristics at the injector exit are shown for the case when the filed amplitudes in the fifth resonator are the same.

***Table 3.** Computational parameters of the gun and beam characteristics*

Parameter	Value
Cathode voltage, kV	-25
Cathode radius, mm	2.5
Normalize beam emittance (1σ), π·mm·mrad	4.1
Distance from the front cut of the anode aperture to the beam waist, mm	19
The beam radius in the waist, mm	1.1
Beam current, mA	245

***Table 4.** Beam characteristics at the injector exit*

Name	Values		
	f_O	f_O-0.2MHz	f_O+0.2MHz
Normalized emittance (1σ), $\varepsilon_{rms\ x,y}$ π·mm·mrad	9	8.8	9
Beam size $4\sigma_{x,y}$, mm	2.5	2.5	2.5
Bunch phase length Δφ (for 70% of particles),°	7.7	8.9	7.9
Energy spread ΔW/W, (for 70% of particles), %	3.9	3.9	3.9
Maximal energy W_{max}, keV	1022	1022	1022
Average energy W_{avr}, keV	948	947	947
Energy in the maximum of the energy spectrum, keV	1012	1012	1012
Widths of the vertical and horizontal beam profiles (for 70% of particles), mm	1	1.1	0.96
Capture coefficient k_3, %	89.3	89.5	89.2

As it is seen from the table, with the change of the operating frequency the beam characteristics change insignificantly. For instance, the phase length relative change does not exceed 15%.

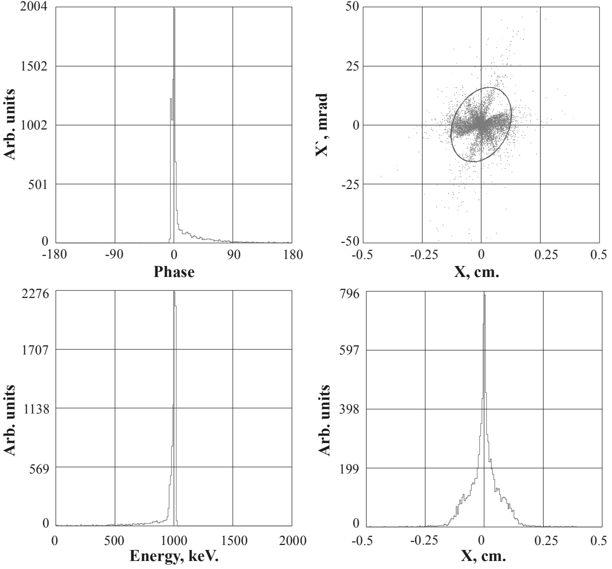

Fig.3. Beam characteristics at the injector exit

In the simulation there have been obtained the dependences of the energy and phase spectrum width, the average electron energy, the emittance, the capture coefficient at the injector exit at various values of the accelerating field (see Fig.4). The values of the energy and phase spectrum are given for 70% of all the particles at the injector exit.

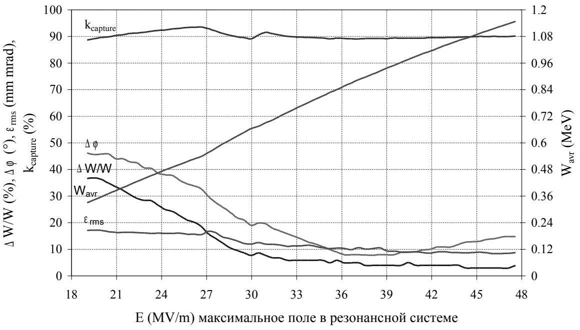

Fig. 4. The dependences of the energy and phase spectrum width, the average electron energy, the emittance, the capture coefficient at the injector exit at various values of the accelerating field

As it is shown in the figure, at the change of the accelerating field amplitude from –12% to 8% of the optimal value the phase spectrum width remains within 10°.

4. CONCLUSIONS

Based upon our developed conception of using the periodic structures with evanescent oscillations for the bunching and preliminary accelerating of the electron beam, the simulation has been carried out and the construction of the new injector system linac with the resonant system optimized geometry has been developed. The injector with the optimized field distribution allows electron bunches to be formed effectively and to be accelerated from an initial energy of 25 keV up to 1 MeV at a current up to 245 mA. The developed bunching system will allow obtaining of an electron beam at the linac exit for the "NESTOR" storage ring with the following basic parameters: W_{avr}=948 keV, $\Delta W/W$=3,9%, $\varepsilon_{rms\ x,y}$=9 $\pi\cdot$mm mrad, $\Delta\varphi$=7.7°.

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ИНЖЕКТОР ЭЛЕКТРОНОВ ДЛЯ ЛИНЕЙНОГО УСКОРИТЕЛЯ-НАКОПИТЕЛЯ "НЕСТОР"

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В работе приведены результаты расчета группирующей системы и моделирование движения электронов в инжекторе S–диапазона. Инжектор состоит из низковольтной диодной электронной пушки и группирователя на основе резонансной системы с нераспространяющимися колебаниями. В устройстве реализовано такое распределение поля на оси, при котором его амплитуда нарастает от точки инжекции электронов до выхода группирователя. Проведена оптимизация резонансной системы, которая позволяет получить на выходе инжектора электронные сгустки с фазовой протяженностью меньше 10 градусов и шириной энергетического спектра меньше 5% (для 70% частиц).

ІНЖЕКТОР ЕЛЕКТРОНІВ ДЛЯ ЛІНІЙНОГО ПРИСКОРЮВАЧА-НАКОПИЧУВАЧА "НЕСТОР"

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У роботі приведено результати розрахунку групуючої системи і моделювання руху електронів в інжекторі S–діапазону. Інжектор складається з низьковольтної діодної електронної гармати та груповача на основі резонансної системи з коливаннями, що не розповсюджуються. У пристрої реалізовано такий розподіл поля на осі, при якому його амплітуда наростає від точки інжекції електронів до виходу груповача. Проведена оптимізація резонансної системи, яка дозволяє одержати на виході інжектора електронні згустки з фазовою протяжністю менше 10 градусів і шириною енергетичного спектру менше 5% (для 70% частинок).