THE INVESTIGATIONS OF THE BEAM CHARACTERISTICS IN THE ELECTRON INJECTOR BASED ON RESONANCE SYSTEM WITH EVANESCENT OSCILLATIONS

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Abstract

The results of experimental electron S – band injector on the evanescent oscillations are presented. The beam characteristics have been measured depending on the resonance system RF power and current injected. The processes under RF training are described. The tests have shown that the injector provides the electron beam formation with the current 0.9 A at the energy 800 keV and normalized transverse emittance 30 π·mm·mrad.

INTRODUCTION

The electric field intensity increasing on the injector resonance system axis while charged particles bunching allows to improve formation of the short bunch of particles at retaining minor energy spread [1-3].

The realization of that principle in the S-band electron injectors with using the biperiodic resonance system with magnetic coupling was suggested in [4] and has been developed in [5]. The increasing field along the injector axis has been realized by the special choice of coupling coefficients of adjacent resonators.

For implementation of the increasing field along the resonance system axis in [6-9] it was suggested to use the section of periodic disc-loaded waveguide excited in the stop-band. The injector designed on this principle consists of five coupled resonators (see fig. 1). The coupling has been realized through the central apertures for the beam pass, the RF-power is supplied to the fifth resonator also coupled with the rectangular waveguide. The eigenfrequency of that resonator, close to the operating frequency of the accelerator is above of frequency of the π mode of the homogeneous infinite disc-loaded waveguide consisting of resonators which sizes coincide with the sizes of the second, third, and forth resonators of the injector. In such system there are five longitudinal modes in the range of the lowest pass-band. The axial field amplitude in the centers of the resonators of the operating longitudinal mode sharply decreases from the fifth resonator to the first one (in the injector designed by a factor of 150). The field in the adjacent resonators is phase-reversal in this case. The field amplitudes of the rest four longitudinal modes are minor in the fifth resonator. Non-resonance excitation of adjacent longitudinal modes by the bunches being formed results into the change of the operating mode field structure. The simulation, which results are presented in [7], has shown that the change of field amplitudes correlation in the first and fifth resonators at the beam current acceleration up to

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1.5 A doesn't exceed 3.7%. The experimental testing of the field structure stability in the injector resonance structure at intense beam acceleration is a subject of interest. The injector testing with the current up to 200 mA, which results are presented in [10], have shown the stability of its work in that condition. In this article we present the injector test results at the current up to 1 A.

EXPERIMENTAL SETUP

The injector design is schematically shown in fig. 1. As the electrons source the diode electron gun with impregnated 14 mm diameter cathode, pulse current 1.1 A at voltage 25 kV has been used. The coupling coefficient of the feeder 4 (Fig. 1) with the resonance system equals 4.6. Such value has been chosen to form the beam with the current 1 A.
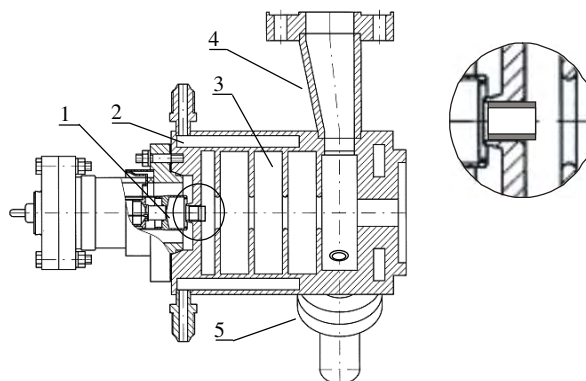

Figure 1: Simplified view of the buncher (1 – electron gun; 2 – cooling ducts; 3 – resonant system; 4 – waveguide; 5 – tuning unit).
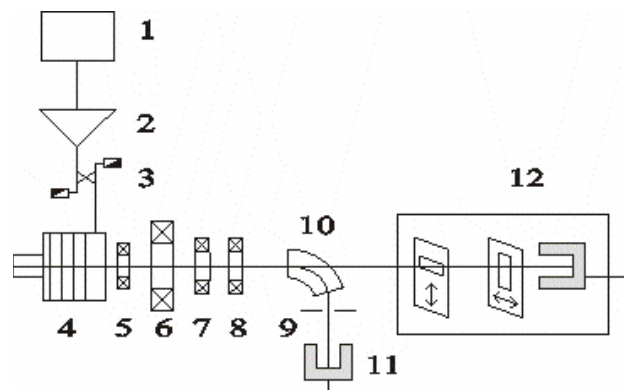

Figure 2: Test stand scheme

The field amplitude measuring has been carried out by the pickup loops built in the first and fifth resonators. For the thermostating the inside cooling ducts have been used.

The injector temperature can be adjusted with the accuracy ±0,2°C in the range 30÷50°C.

The experimental study of the injector with the beam has been carried out at the test bench (see Fig. 2) consisting of the high voltage modulator 1; the klystron KIU-12 2; the adjusted directional coupler 3 (10.4÷22.8 dB); the injector investigated 4; the beam current transformer 5; the axially-symmetric lens 6; the quadruple lens 7; the steering coils 8; the collimator 9; the magnetic analyser 10; the Faraday cup 11 and the transversal parameter monitoring device 12 consisting of the pair of moveable collimators and the Faraday cup.

EXPERIMENTAL RESULTS

At gun current absence under the input RF-power from 0.6 MW and above, the oscillations of envelope of a signal from the first resonator have been observed (see fig. 3). The field amplitude in the center of the resonator was about 1.4 kV/cm. On the envelope of a signal from the fifth resonator the oscillations were absent.
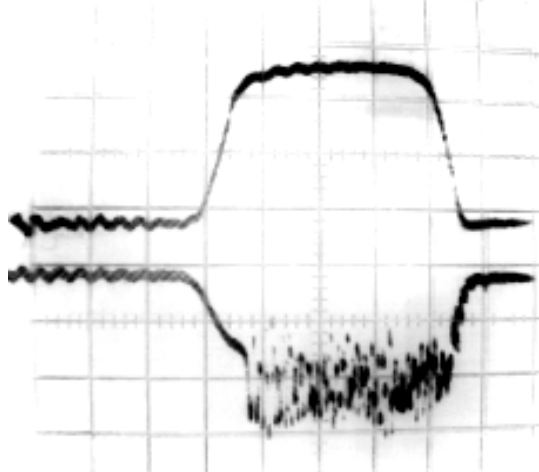

Figure 3: Field impulses: at the bottom – in the first, at the top – in the fifth resonator.

The frequency spectrum analysis from the first resonator pickup loop has shown the presence of five frequencies that correspond to the five longitudinal modes of the resonance system. When the oscillations started in absence of high voltage on the electron gun the cathode was exposed to the electron bombarding. Energy of electrons was up to 1.5 keV at their current up to 10 mA. At the beam accelerating that instability resulted into slight output current oscillations.

The peculiarities of the described instability depended on the duration of RF-conditioning. Though, it was failed to eliminate the effect completely, whereas the accelerating field increasing process has been successfully accomplished within 24 hours without substantial amount of breakdowns.

We have observed the delay time between leading edge of a RF pulse and beginning of the oscillations. The delay was dependent on supplying RF power. Such factors as the presence of delay time and low field threshold

appearing of the observed instability under the condition of large transit angles of electrons between the cell walls indicate progress of the polyphase secondary emission electron discharge [11] in the first resonator. As it is known, for the progress of such discharge the secondary emission coefficient of the walls is required to be over 2, which is conditioned by the surface pollutions.

For elimination of that multipactor the first resonator's geometry has been changed: into the inlet for the beam pass the thin-walled tube has been inserted (see fig. 1). At that the field amplitude on the axis in the first resonator, according to the calculations, has decreased by factor of 10, and in the other resonators it remains almost unchangeable. As a result, to obtain the calculated beam energy it was the necessary to increase RF-power supply on 15%.

Next testing stage consisted of the measurements of the injector beam characteristics. The measurements have shown the increase of the optimal RF-power and relative energy spectrum width at the beam current increasing. As it is seen from fig. 4, the minimum of a energy spectrum width has not been achieved, unlike the measurements at the low beam loading [10]. It is connected with the lack of input RF-power.
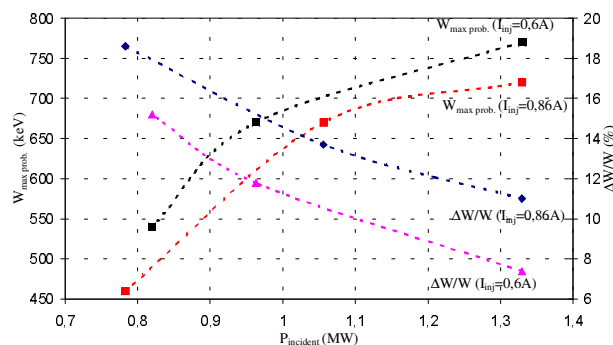

Figure 4: Energy spectrum width and electron energies in maximum of spectrum depending on input RF-power.

Fig. 5 shows the field envelopes in the first and fifth resonators at the gun current 1.1 A (current on the injector exit was 0.86 A) and at the absence of gun current.
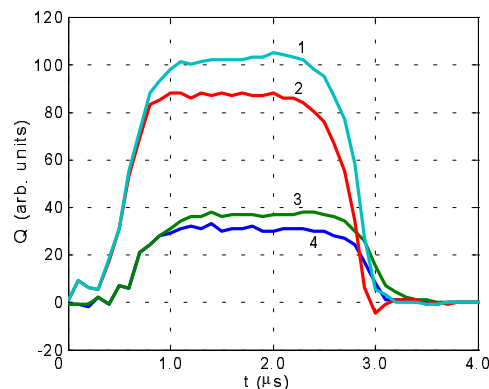

Figure 5: The envelopes of field in the first (curve 4) and fifth (curve 2) resonators with and without current (curves 3 and 1).

Change of the field amplitude relation in resonators 1 and 5 with and without current is 2.3%. The analogical calculated value [7] is 1.8%. It can be seen that the resonance system self-excitation at the currents up to 1 A is absent, and the field distribution change is negligible.

In fig. 6 the measured energy spectrum for the two current values at injector exit is represented.
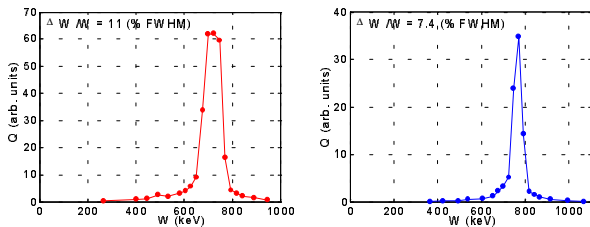

Figure 6: Energy spectrum measured at the injector exit at the input power 1.3 MW and current 0.86 A (left) and 0.6 A (right).

In Table 1 the beam parameters at injector exit measured and calculated are represented at the input power 1.3 MW. The data are given for the case when the energies in the maximum spectra of measured and calculated beams are the same.

Table 1

Parameter	Experiment	Simulation
Cathode voltage, kV	-25	-25
Cathode diameter, mm	14	14
Beam current at the gun exit, A	1.1	1.1
Operating frequency, MHz	2797.15	2797.15
Unloaded quality factor	11000	12298
Shunt impedance, MOhm/m	18	18.6
Coupling coefficient with the waveguide	4.6	4.6
Beam current at the injector exit, A	0.86	0.87
Normalized emittance, $\pi \cdot$mm$\cdot$mrad	19	17
$\Delta\varphi$ (FWHM), degree	-	7.1
$\Delta W/W$ (FWHM), %	11	11
Energy at the maximum of an energy spectrum, keV	720	720

It should be noted that the acceptance of the emittance measuring channel in this series of experiments was insufficient for carrying out the correct measuring. The experimental emittance value given in the table 1 have been calculated from the beam profile width containing about 30% beam particles at the injector exit. The obtained emittance value is well-agreed with simulation results of the emittance measuring process.

CONCLUSION

The carried out experiments has shown that the beam parameters at the injector exit agree with calculated ones.

The appearance of multipactor in the first resonator of injector has been eliminated by the change of the geometry of the first resonator paraxial area.

At the chosen coupling coefficients of the injector resonators the non-resonant excitation of the adjacent longitudinal modes doesn't result in significant change of the field structure on the axis that allows to form the beam with the current up to 1 A.

The designed injector can be used in the technological and research accelerators.

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