TEST RESULTS OF INJECTOR BASED ON RESONANCE SYSTEM WITH EVANESCENT OSCILLATIONS

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Abstract

Report presents the results of tune-up and tests of the compact electron S – band injector consisting of the low-voltage diode electron gun and the buncher based on the resonant system with the evanescent oscillation. In the considered buncher electrical field increased from beam entrance to an exit. The injector designed for bunching of electron beam with initial energy of 25 keV and pulse current of 300 mA and accelerating it to the energy of 1 MeV.

INTRODUCTION

The injector substantially defines beam characteristics on linac exit. In [1-4] it was offered to use for this purpose the section of homogeneous dick loaded waveguide exited on the frequency that lies beyond the pass-band. As the buncher a chain of five coupled cavities has been used. The coupling of cavities implemented through central holes for beam passing. For realization of required on-axis field distribution, the operation frequency of a buncher, which was close to the eigen frequency of the last cell, was selected higher than the frequency of the "π" mode of a remaining part of the buncher. In this case the phase advance of a field on a cell remained equal π. By the simulation results the electron injector has been elaborated and made.

In this article we present the results of the injector system created comprehensive testing.

EXPERIMENTAL RESULTS

The diode electron gun with impregnated 5 mm diameter cathode with anode voltage 25 kV and pulse current up to 0.3 A has been used as the electrons source. In Fig. 1 the cathode assembly and the focusing electrode of the electron gun are represented.

At the first stage the compound parts of the resonance bunching system have been made and the resonance system preliminary tuning has been carried out. The eigen frequency, quality factor and the shunt impedance of the resonator have been equal to 2797.15 MHz, 11000 and 18 MOhm/m consequently. The choice of coupling coefficient 4,64 with waveguide has been determined taking into account the possibility of using the injector for bunching and accelerating the intense electron beams (up to 1.5 A) as well. The resonance frequency could have been changed within ± 9 MHz by means of a special device. Then the resonators have been soldered in the vacuum oven with the use of silver-based hard solder. After the brazing the final tuning of the resonance system has been held. In Fig. 1a the bunching system in its final condition is represented.

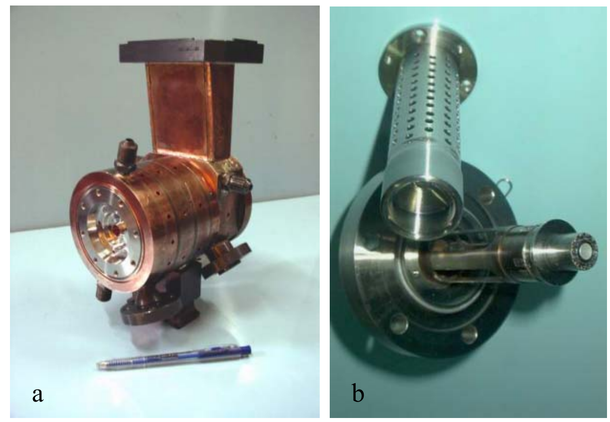

Figure 1: a – The bunching system; b – the cathode assembly and the focusing electrode.

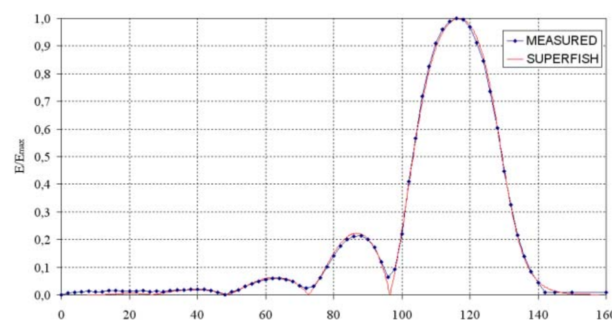

Figure 2: The electrical field amplitude distribution on the axis.

In Fig. 2 the measured field amplitude distribution on the resonance system axis is represented, as well as that of calculated, carried out with the help of SUPERFISH [5].

The experimental studies of the injector have been carried out at the special stand that provided the RF-power for the resonance system, the power for the electron gun and the beam characteristics measurements. The experiments included the beam emittance measurements and the electrons energy spectrum at the injector exit at various descending RF-power value. The stand scheme is represented in Fig. 3

The injector cavity temperature is regulated over the range from 30 to 50°C with the possibility of maintaining the constant at the given point with the accuracy ±0,2°C. Two measuring pickup loops for the RF-field diagnostics in the resonance system have been installed. The pickup loop #1 is situated in the first short resonator, #2 – in the fifth resonator.

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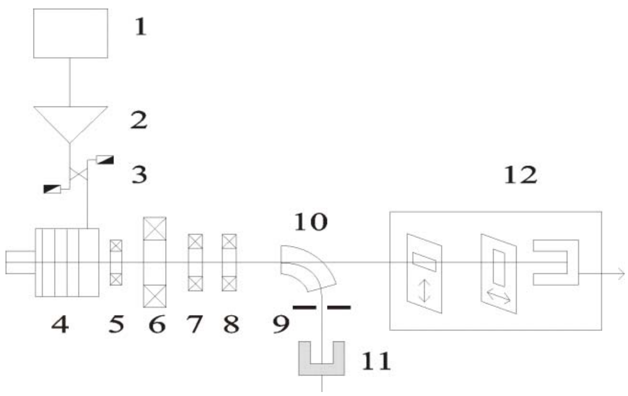

Figure 3: The testing stand scheme: 1 klystron modulator; 2 klystron (P_{out} =16 MW, τ=2,2 μs).; 3 directional coupler (-10 - -22 dB); 4 injector; 5 beam current transformer (BCT); 6 axially-symmetric lens; 7 quadruple lens; 8 the beam position adjustors; 9 collimator; 10 magnetic analyzer; 11 Faraday cup; 12 the beam transverse distribution and emittance measurement system.

After setting the injector at the testing stand the RF processing of the resonance system has been carried out. During the injector testing the instability has been discovered. With the instability appearing at the RF field pulse envelope from the detector in the first resonator the oscillations and corresponding beam current modulation at the injector exit have been observed. With that at the RF field pulse envelope curve from the detector in the fifth resonator the oscillations have not been observed.

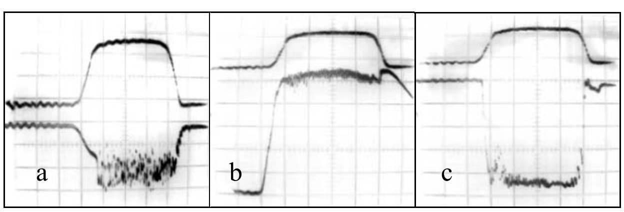

Figure 4: Oscillograms: a – the field in the fifth resonator (upper ray) and the field in the first resonator (lower ray) at the moment of instability appearing; b – the field in the fifth resonator and the injector current at BCT (38 mA/div , 0.5 μs/div); c – the field in the fifth resonator and the current on the Faraday cup (37 mA/div , 0.5 μs/div).

In Fig. 4a the envelope curve of the RF- field pulses in the first and fifth resonators are shown. The frequency spectrum analysis from the first resonator's pickup loop has detected the presence of five frequencies corresponding to the frequencies of the five modes of the resonance system. Therefore the oscillations observed in the first resonator are the result of the signals with various frequencies composition. After the subsidiary experiments we have come into opinion that such instability is connected with the appearing of the multipactor in the first resonator.

In order to eliminate the multipactor and the excitation of the resonance system, the geometry of the first resonator has been changed – into the input aperture for the beam pass the thin-wall tube has been inserted (see Fig. 5)

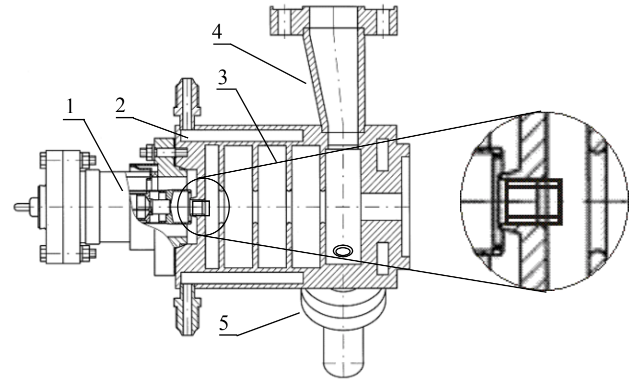

Figure 5: Simplified view of the buncher (1 – cooling ducts; 2 – resonant system; 3 - waveguide; 4 - tuning unit).

As the result of geometry changing the field amplitude on the axis in the first resonator, according to the calculations, decreases 10 times, and in the rest of the resonators it hasn't changed practically. According to the simulation carried out it requires the 5÷15 % increasing of the input RF power for achieving the optimal bunching system working regime. The carried out measurements have shown that the steps taken have eliminated the instability – the oscillations at the RF field pulse in the first resonator (Fig. 6) and the current modulation have not been observed.

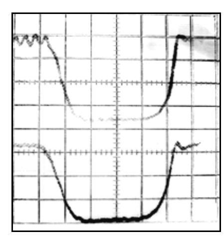

Figure 6: The field in the fifth resonator (upper ray) and the field in the first resonator (lowed ray).

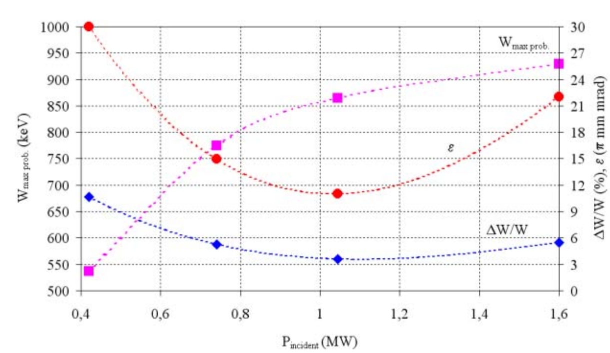

Figure 7: The energy spectrum width, energy at maximum energy spectrum and normalized emittance from the incident RF-power.

During the further testing of the injector the main beam parameters have been measured at the injector system exit and their dependence on the RF power (see Fig. 7). In

Fig. 8 the experimentally measured electron energy spectrum at the injector exit is depicted.

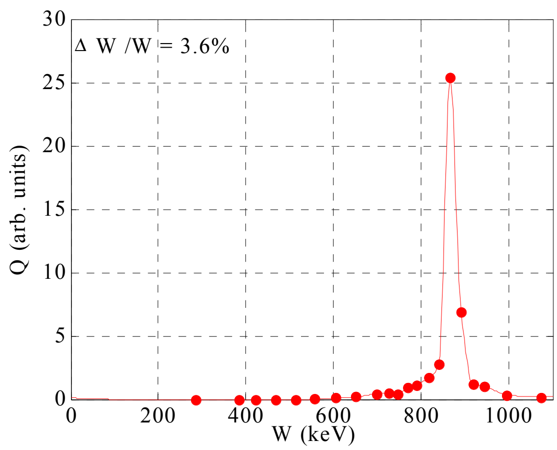

Figure 8: Measured energy spectrum at the injector exit at the incident RF-power 1.0 MW.

In Table 1 the beam parameters at injector exit measured and calculated are represented. The data are given for the case when the energies in the maximum spectra of measured and calculated beams are the same. The electron beam characteristics are measured at feeding power 1.0 MW.

Table 1: Parameters of the injector.

Parameter	Experiment	Simulation
Cathode voltage, kV	-25	-25
Cathode radius, mm	2.5	2.5
Beam diameter in cross-over, mm	1.4	2.2
Beam current at the gun exit, A	0.22	0.22
Operating frequency, MHz	2797.15	2797.15
Unloaded quality factor	11000	12298
Shunt impedance, MOhm/m	18	18.6
Beam current at the injector exit, A	0.16	0.191
Normalized emittance, π·mm·mrad	16	15
Δφ (70% particle), deg.	–	21.6
ΔW/W (FWHM), %	3.6	2.3
Energy at maximum energy spectrum, keV	865	865

The emittance represented in the table has been measured by the three-gradient method using the quadruple lens (see Fig. 6). The calculation has been carried out with PARMELA [6]. It shows that the measured beam parameters meet the calculated data. That's why it can be supposed that the phase length of bunches Δφ should meet the calculated value. At present a special stand for bunch length measurement has been prepared and mounted. After carrying out these measurements the injector will be placed at the S-band electron linac with beam energy variation over a wide range [7].

CONCLUSION

The carried out experimental research has shown that the beam parameters meet the main requirements stated at the injector elaboration. At the slight change of the resonance system geometry the resonance system parasite excitation caused by the multipactor has been eliminated. The results of the measurements meet the calculated data.

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