HF STRUCTURE OF BETA-8 ELECTRON RESONANCE ACCELERATOR

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Abstract

RFNC-VNIIEF is developing a powerful resonance electron accelerator BETA-8, operating in the mode of continuous wave generation. The accelerator is developed on the basis of half-wave coaxial cavity, excited on the wave of T1 type.

The paper presents calculation results of accelerating cavity with operating frequency 100 MHz, as well as an inductive unit of HF power input (UPI) meant for transfer of continuous HF signal on the operating frequency with an average power level 600 kW. Calculation results are proved by measurements of HF characteristics of the cavity assembled together with UPI and a coupling wave guide.

The location of an indicator loop–pickup, mounted in a coupling wave guide is computed. The given loop–pickup is meant for operation in a frequency feedback circuit for the HF generator.

INTRODUCTION

Resonance electron accelerator BETA-8 (Figure 1) is being developed in RFNC-VNIIEF. Development of an accelerating facility with average electron beam power up to 300 kW with a control range of accelerated electron energies - from 1 up to 8 MeV and meant for study of radiation resistance and radiation tests of large-scale objects is based upon requirements, specified earlier [1, 2].

Figure 1: General accelerator view.

Below are reported results of three-dimensional electrodynamic calculation of basic components of accelerator HF structure as well as calculation methods of its radio-engineering tuning.

ACCELERATING CAVITY, UPI AND FEEDBACK WITH GENERATOR

A coaxial cavity, a transmitting feeder – coaxial wave guide and UPI are basic elements of BETA-8 accelerating HF structure. Estimated electric field distribution inside the cavity, in the electron acceleration region is given in fig. 2.

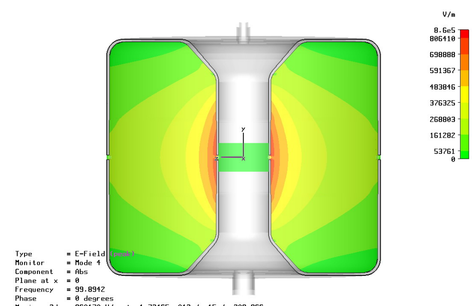

Figure 2: Waveform of electric field strength in the coaxial cavity median longitudinal plane.

The basic cavity's overall dimensions are: 1) inner conductor radius – 210 mm, 2) outer conductor radius – 1040 mm, 3) cavity height (longitudinal size) – 1626 mm. Electrons are accelerated in the cavity median transverse plane. The basic estimated electrodynamic characteristics (EDC) of the coaxial cavity comprise: resonance frequency f_0 = 99.9 MHz; kinetic energy gain per one pass We = 1.5 MeV; transit time factor T = 0.777; loss power within the cavity walls P_{loss} = 165.2 kW; resonator quality factor Q_0 = 56088; effective shunt impedance $Z_{sh.ef}$ = 15.25 MOhm.

At the first stage to supply the cavity, a single module of HF generator is used. At the matching mode it generates a signal with average power 180 kW and frequency ≈100 MHz [3].

UPI, developed in SSC RF IHEP (Protvino, Russia) is meant for operation as a connector, allowing connection of the transmitting feeder with accelerating coaxial cavity.

The main specification of UPI involves the following: coupling with the cavity – inductive; device input - coaxial, with wave resistance 50 Ohm; sizes of entrance air-filled coaxial feeder - Ø160/70 mm; UPI operates at any frequency in the range 98 - 102 MHz; operating frequency – 100 MHz; transmitting HF power in the mode of pulse and continuous generation – up to 600 kW; UPI provides an interface level of the feeder with a cavity with a voltage standing-wave ratio (VSWR) ≤ 1,2 in the frequency range 98-102 MHz.

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The basic element of UPI is an inductive loop, required for magnetic coupling of the transmitting feeder and the cavity. The loop is mounted on the cavity end wall in the plane, perpendicular to magnetic field. Fig. 3 shows the place of the loop mount in the cavity.

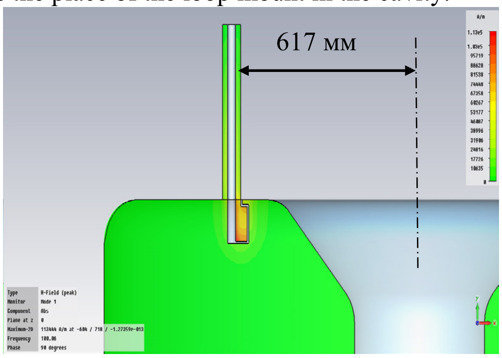

Figure 3: Place of the loop mount in the resonator.

To match the resonator input impedance and the input coaxial, a circuit with quarter-wave transformer and a parallel closed stub is chosen. Figure 4 presents equivalent UPI circuit.

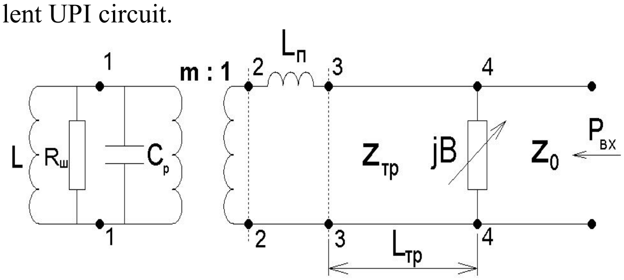

Figure 4: Equivalent UPI circuit.

The generator feeder, a nondissipative matching stub and an output line form a coaxial tee. For reasons of design, accepted is the following arrangement: two tee arms (a stub and a quarter-wave transformer) have a common axis, and HF signal is supplied from the arm side, perpendicular to this axis, (figure 5).

Figure 6 shows UPI, mounted on the accelerating cavity with a connected coaxial feeder.

VSWR measured experimentally on the input of the system, consisting of a transmitting feeder, UPI and an accelerating cavity is given in fig. 7. At resonance frequency (99.857MHz) VSWR=1.05.

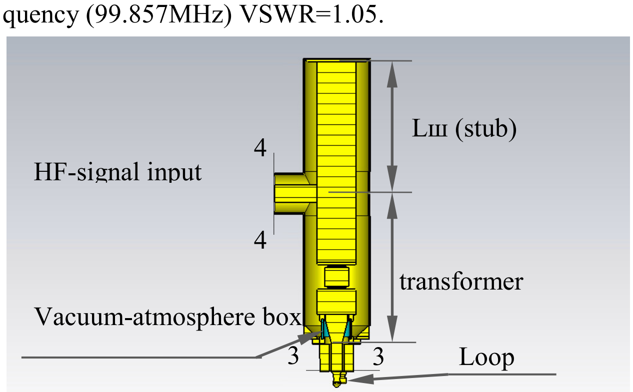

Figure 5: UPI arrangement.

Figure 6: Feeder, UPI and cavity ready-fitted.

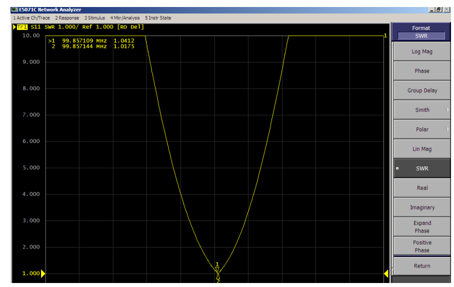

Figure 7: Experimentally measured VSWR at the UPI input assembled together with the cavity.

When switching on the HF generator with the accelerating coaxial cavity, two circuits of generator-to-cavity feedback should be put into operation. The first circuit – the frequency feedback one, allows tuning of the HF generator operating frequency to the resonance frequency of the coaxial accelerating cavity. The basic element of the given circuit is a magnetic coupling indicator loop-pickup, mounted in the transmitting feeder, connecting the HF generator and UPI, at the point of voltage node origin providing the possible mismatch.

The place of indicator loop mount in the transmitting feeder was calculated. Below are given results of three-dimension electrodynamic calculation of HF structure (Figure 8), consisting of the transmitting feeder, UPI and cavity.

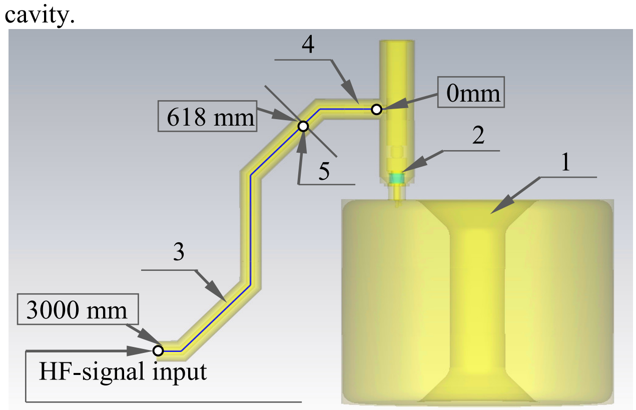

Figure 8: HF-structure design model. 1-accelerating cavity; 2- UPI; 3 – feeder; 4 – projecting line; 5 – cross-section for indicator loop mount.

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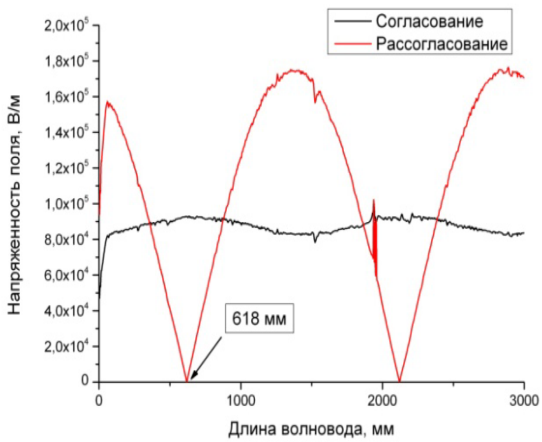
Figure 9 presents distribution of electric strength in the transmitting feeder in cases of match and mismatch. In the case of mismatch the standing-wave is formed in the feeder, the first voltage node originates at a distance of 618 mm from zero on the projecting line.

Thus, there is specified a place, where it is possible to mount the indicator loop-sensor of a frequency circuit of HF generator feedback.



Wave guide length

Figure 9: Calculated dependencies of electric field strength along the feeder axis at matching and mismatching.

To primarily try-out modes of functioning the feeding HF generator module (with average power up to 180 kW) and accelerating complex technology systems, there have been calculated, designed and tested a matched load (Figure 10). The load involves two resistors C2-25 (50 Ohm, 100 kW). The structure matching provides a quarter-wave transformer, experimentally measured VSWR at the input is 1.15 on the operating frequency 100 MHz.

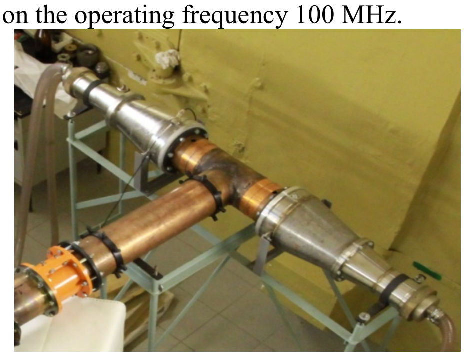


Figure 10: Matched load.

CONCLUSION

The HF-structure of BETA-8 resonance electron accelerator is represented.

The basic structure element is an accelerating coaxial half-wave cavity with operating frequency 100 MHz. At HF supply with average power more than 165 kW it allows obtaining the kinetic energy gain of 1.5 MeV accelerated electrons per a single full pass in its median transverse plane. The cavity was calculated, designed, manufactured and tested. Its experimentally obtained EDC with satisfactory precision coincides with calculated ones.

To match the resonator with the HF feeder, UPI was calculated, designed and manufactured. This unit allows practically with no power losses (with VSWR =1.05 on the resonance frequency) HF-signal transfer into the accelerating cavity.

Three-dimension electrodynamic calculations were carried out. They allowed determination of the location of the indicator loop, operating in the frequency feedback circuit, on the transmitting feeder. Such calculations significantly simplified determining of its location in practice.

There was calculated, designed, manufactured and tested the matched load, allowing tests of HF generator module and accelerator technological system at high average power up to 200 kW.

REFERENCES

[1] S.A. Zhelezov, N.V. Zavyalov, et al. Design of an electron continuous resonance accelerator.// VIII Khariton lectures on the problems of high-dense energy physics. Report Collection. 2006. Sarov – P.122-128.

[2] V. Zavyalov, S.A. Zhelezov, et. al. A CW Electron Accelerator. The Planned Design and Electro-physical Characteristics.// Problems of Atomic Science and Technology. 2006 №2 Series: Nuclear Physics Investigations (46), – P.8-10.

[3] Gladyshev E.N., Gordeev V.S. et al. Status of works on development project for continuous electron resonance accelerator BETA-8// Proceedings of RFNC-VNIIEF. Ser. Science and Research Edition. 2015. Issue 20. P. 1. P. 184–193.

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