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ACCELERATING STRUCTURE OF 8 MeV ELECTRON LINAC

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Abstract

The paper presents results of three-dimensional electrodynamic calculations of an accelerating section of a resonance electron linear accelerator and input and output matching devices (couplers), as well as its electron dynamics calculation.

INTRODUCTION

Since 1994 a linear electron resonance accelerator LU-10-20 [1], meant for radiation materials processing and radiation processes study has been functioning in RFNC-VNIIEF. Accelerated electron energy – up to 10 MeV, beam average power – up to 12 kW. This accelerator has demonstrated its urgency when conducting radiation studies and tests.

Today modernization of LU-10-20 accelerator, involving an accelerating section and RF power systems, is being conducted. An accelerating section is meant for electron beam acceleration up to nominal energy and represents a complex resonance traveling wave RF structure, consisting of a disk-loaded waveguide and input and output couplers.

ACCELERATING STRUCTURE TYPE

A basic element for any accelerator is a microwave oscillator. To modernize LU-10-20, MI-470 pulsed magnetron manufactured by corporation Scientific Production Enterprise «Toriy» (Moscow) was chosen. Magnetron MI-470 supplies output pulsed power 10 MW with pulse duration from 3 up to 10 μs. Magnetron operation frequency range – (1883÷1889) MHz.

As an accelerating section for LU-10-20 modernization there was chosen structure based on disk-loaded waveguide (DLW) with variable geometry, operating on the traveling wave with mode 2π/3, similar to LU-10-20 current section. Operating frequency of accelerating structure at mode 2π/3 – 1886 MHz. Main arguments for selecting such a structure is experience availability for development and operation of linear accelerators with DLW, simplicity and cheapness of manufacture, availability of aperture for electron beam of larger diameter and simpler feed circuit as compared to structures on standing wave. Using reference data [2] there was determined preliminary geometry of the given accelerating structure, consisting of 10 cells buncher and 32 regular accelerating cells, and electron dynamics calculations were performed in one-particle approximation [3].

CELL GEOMETRY OPTIMIZATION

A purely experimental way for size fitting of accelerating cells from initial approximation to more precise ones represents a long process and is rather a labor-intensive occupation. At that during adjustment each cell undergoes processing on the turner not less than 3..5 times, what inevitably results in degradation of accelerating cell pure working surface. In order to reduce the number of adjustment cycle or to exclude process at all, the accelerating cells preliminary geometry was refined in resonance mock-up model.

To determine resonance frequencies, corresponding to definite oscillation modes, and the following calculated cells geometry adjustment to working frequency, the resonance mock-up electrodynamic model (Fig. 1) was developed. The resonance mock-up uses a property of periodic structures – availability of reflection symmetry planes, perpendicular to translation axis. For the disk-loaded waveguide one of reflection symmetry planes is placed symmetrically to adjacent diaphragms.

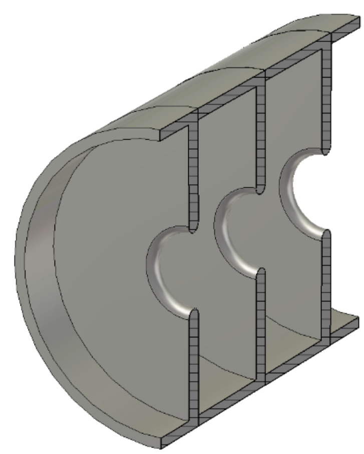

Figure 1: Resonance mock-up model.

In the resonator like that in Fig. 1, consisting of 4 cells, 4 modes become excited. Resonance frequency of the given model on 2π/3 mode was adjusted to the operating frequency 1886 MHz in the frequency band ±40 kHz by changing cell inner diameters (diameter change by 0.01 mm brings to frequency change by 52 kHz). After satisfactory result was achieved one of cells was replaced, and cell adjustments was not continued till all 42 cells were adjusted. Geometry optimization results are given in Fig.2.

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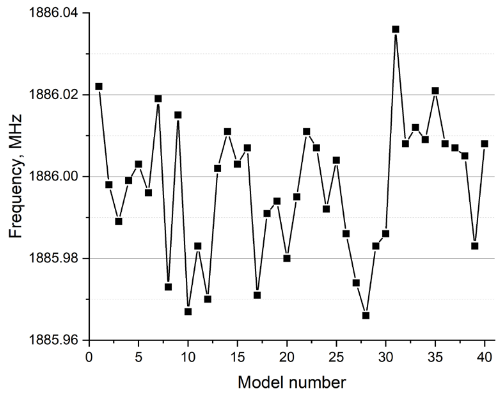

Figure 2: Resonance model adjustment result.

Accelerating field distribution on 2π/3 mode in one of model is given in Fig. 3.

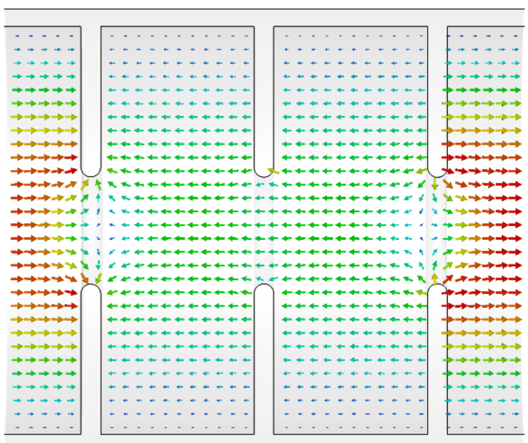

Figure 3: Distribution of accelerating field on mode 2π/3 in the model.

CALCULATION OF ACCELERATING SECTION AND COUPLERS

The traveling wave accelerating structure type, selected as a base for accelerator's modernization, implies usage of input and output matching devices (couplers), which are connected to a rectangular waveguide through coupling window. Couplers have a connecting pipe located symmetrically with regard to the rectangular waveguide to remove electromagnetic field distribution asymmetry in coupling cell axial region, as well as to provide connection of vacuum pumps. Geometry for both couplers was adjusted for operating frequency 1886 MHz by changing its geometry (coupling cell radius and width and thickness of coupling window. Input coupler was adjusted to VSWR value <1.05 at operating frequency and <1.15 in bandwidth ±2 MHz with the aid of a model with first three accelerating cells and arbitrary load. Output coupler was adjusted to the value VSWR not worse than 1.20 in the range ±1.5 MHz from operating frequency in model, involving accelerating structure and input coupler. Final accelerating section design model with input and output couplers is represented in Fig. 4.

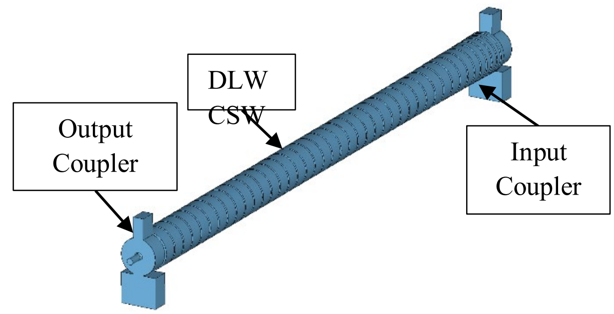

Figure 4: Accelerating structure model.

Quality factor of structure – 17000. The value of calculated shunt impedance is about 55 MOhm/m. Calculated structure filling time by RF power is about 650 ns.

CALCULATION OF ELECTRON DYNAMICS

The obtained three-dimensional model of accelerating section was used for calculation of electron beam dynamics in the accelerator. As transverse focusing there was used a solenoid field 0.1 T.

A single electron bunch with 10 mm radius was injected in accelerating structure during the time corresponding to the period of microwave field (0.53 ns). Electron beam energy – 50 keV. RF power – 8 MW. The calculation took into account losses of RF power on conducting walls.

As a result of calculation the average particle energy was obtained to be 9.1 MeV, capture efficiency by current was – ~60%. Electron spectrum on the accelerator output is given in Fig. 5. Obtained results agree very well with preliminary calculations of electron dynamics [4] (electron energy – 8.79 MeV, capture efficiency – 79%). One can explain a bit smaller particle capture through a negative influence of input coupler, what was neglected in the course of preliminary calculations.

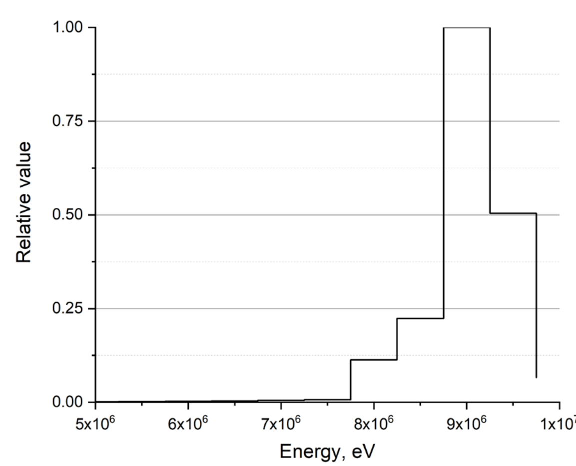

Figure 5: Electron energy spectrum.

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CONCLUSION

This paper presents main results of three-dimensional electrodynamic calculation of the accelerating structure of the linear resonance electron accelerator for energy 8 MeV.

A short ground for selecting the accelerating structure type is given.

The accelerating cells geometry was numerically optimized in order to exclude or reduce, if possible, the number of cells after-treatment stages while tuning the accelerating section at the operating frequency. Specified were optimal geometry sizes of input and output matching devices, also providing matching of the accelerating section and RF generator with VSWR not worse than 1.20 at the bandwidth ±1.5 MHz. Structure main electrodynamic characteristics – quality factor, shunt impedance, structure filling time by microwave power were determined.

Electron beam dynamics in the accelerator's model was numerically investigated.

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