NEW PRESTRIPPING SECTION OF THE MILAC LINEAR ACCELERATOR DESIGNED FOR ACCELERATING A HIGH CURRENT BEAM OF LIGHT IONS*

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Abstract

The results on development and construction of the prestripping section (A/q=4) for multicharge ion linear accelerator (MILAC) designed for acceleration of He^+ ion beam from 30 keV/u to 975 keV/u are presented. In the accelerating interdigital IH structure He^+ ion beam were accelerated using the method of alternating phase focusing with stepped changing the synchronous phase along the focusing period. In order to increase the beam capture into the mode of acceleration, the growing field was used in the initial part of the structure. The elements of the accelerating structure and dynamics of the ion beam were calculated. The maximum calculated current being accelerated was 12 mA with the injection current of 60 mA. All the systems of the accelerating structure were developed, designed, and manufactured; assembling and adjustment of the prestripping section are under way.

INTRODUCTION

At the Kharkov heavy ion linear accelerator (MILAC), (see Fig. 1), [1, 2] the works were carried out with heavy ion beams accelerated to 8.5 MeV/u; studies and development of new methods for accelerations, and improvement of accelerating structures. Investigations on modernization of alternating phase focusing of ion beams in heavy ion linear accelerators with interdigital IH structure allowed to commence to development of a new prestripping section for MILAC accelerator; this will give a possibility to widen the range of scientific and applied investigations in the field of production of unique radionuclides, nuclear reactor industry materials and other problems of nuclear physics.

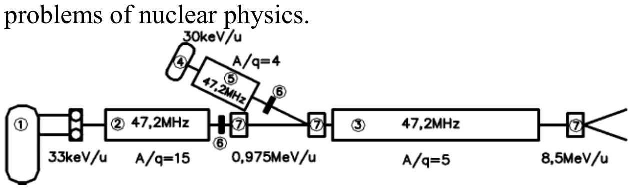

Figure 1: Scheme of the MILAC accelerator.

The existing prestripping section PSS-15 (see Fig. 1, p.2) [3] is designed for accelerating heavy ions with mass-to-charge ration of A/q≤15. It does not fit for acceleration of intense beams of heavy ions (protons, deuterons, helium). Therefore presently next to this section a new initial part of the accelerator (PSS-4) (see Fig. 1, p.5) is being constructed for accelerating only light ions from 30 keV/u to 1 MeV/u meant for significant increase of pulse number of the beam current. After recharging (stripping) (see Fig. 1, p.6) this beam will be output on the acceleration line of the main MILAC section (see Fig. 1, p.6) and accelerated up to 8.5 MeV/u.

PSS-4 MAIN CHARACTERISTICS

As the PSS-4 accelerating structure we chose a modification of the cavity of interdigital type which is presently in use in the main and prestripping sections of MILAC [2, 3]; the cavity is being excited on H_{111} wave. The advantages of this structure in the energy range under discussion lie in its compactness, high acceleration rate and high electrodynamics characteristics providing stable operation and power-saving mode of RF-power supply. The interdigital accelerating structure is also favorable for the simplest and efficient method for providing phase and radial stability of the beam along the accelerating channel which the alternating phase focusing is in the version with the stepped changing of the synchronous phase [4, 5].

Efficiency of this method depends strongly on configuration of each focusing period. The structure of the focusing period in the construction being discussed contains a number of cells where the synchronous phase changes discretely from the cells with negative (grouping) phases passing the cells having the phase smaller in absolute value through φ_s=0 to the zone of positive (focusing) phases and ends with transition to the zone of negative phases. Such arrangement of synchronous phases provides the capture of high current ion beam being injected in the phase angle of 120^o and its radial and phase stability along the accelerating structure, and gives a possibility to hold the acceleration rate at rather high level.

CALCULATION AND OPTIMIZATION THE ACCELERATING STRUCTURE

Taking into account all the listed above aspects a task is set to optimize the design of all the elements of the PSS-4 accelerating structure; such optimization would provide tuning the accelerating structure on the specified frequency (47.2 MHz)and required accelerating field distribution.

A LINACV2 computer code was written in FORTRAN90 [6] for calculation of the longitudinal cell dimensions and ion beam dynamics; this code gives a possibility to work in dialogue mode. The total length of the accelerating structure is 2395 mm. In order to provide

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the required change in the synchronous phases the drift tubes lengths should be changed significantly from cell to cell (from 4.6 mm to 167 mm). With that, the lengths of the accelerating gaps rise smoothly from 12.3 mm to 71.4 mm; that means that the structure is strongly non-uniform. This fact complicates calculations of electrodynamics characteristics.

The method for calculation of the accelerating structure with the stepped change of synchronous phase provides stability of the bunch of particles in longitudinal and transverse directions as the cosine of phase advance of radial oscillations with account of their phase motion lies in the region of phase stability. In the figure 2 results of simulations of He^{+} ion beam dynamics calculated with LINACV2 in the fields and in the structure with input injection current of 40 mA.

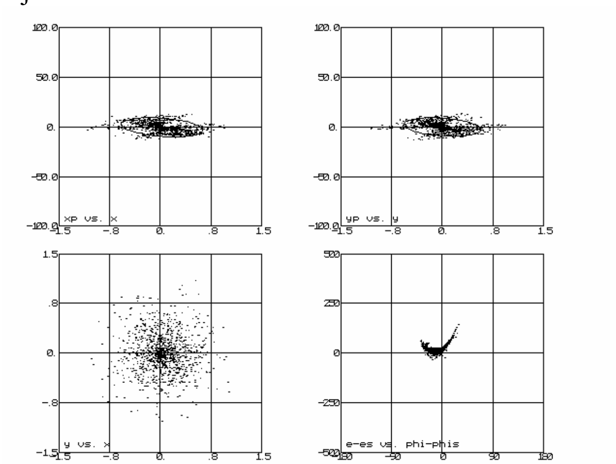

Figure 2: Radial phase portrait and output parameters of the beam at the accelerator output (LINACV2), number of macro particles is 10 000, input current is 40 mA, output current is 12 mA.

The PSS-4 accelerating structure is designed for low input energy of ions (30 keV/u) and high pulsed beam current (12 mA); therefore accelerating field distribution in the initial part of the structure was taken as increasing from cell to cell in order to provide the maximum capture of particles in the mode of stable longitudinal motion. In this case the width and depth of the potential well in which the particles move increases significantly.

DESIGN FEATURES THE ACCELERATING STRUCTURE

Calculations of constructive and electrodynamics characteristics were carried out in 3D version. The procedure of 'manual control' was used which means that the geometrical sizes were sequentially changed for obtaining the required values of necessary characteristics. In the process of optimization parameters for the elements of the structure (cavity diameter, cavity shape, the drift tube diameters, diameters of the rods of the drift tube holders) were adjusted to the required values. In the process of tuning the end resonance tuning elements were used [2] which represent quarter wave oscillators; on the side of the oscillator facing the side wall of the cavity a control piston is placed which can move in longitudinal direction. Such systems are installed on the input and output ends of the cavity (see Fig. 3).

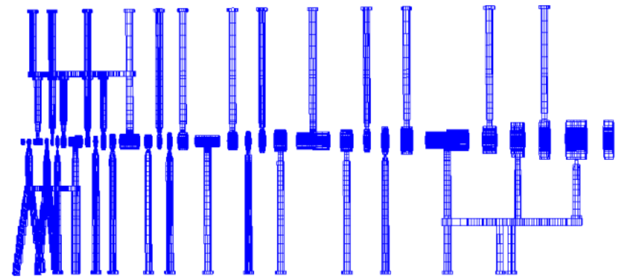

Figure 3: Schematic view of the PSS-4 accelerating structure.

The optimization process appeared to be very complicated due to a difference in synchronous phases and, therefore, differences in drift tube lengths along the focusing periods which is an intrinsic feature of the alternating phase focusing (APF with SCP) which we used. The number of calculation cycles was several tens. As a result of these calculations the data were obtained which ensured completion of the task.

The results of calculations of geometric and electrodynamics characteristics are presented in the Table 1.

Table 1: Geometric and electrodynamics characteristics accelerating structure.

Input ion energy	30 keV/u
Output ion energy	975 keV/u
Operating frequency	47.2 MHz
Growing accelerating field	9÷85 kV/cm
Total acceleration rate	1.6 MeV/m
Cavity length	2395 mm
Number of accelerating cells	32
Cavity diameter	107.5 cm
Pulsed current of accelerated ions	12 mA
Angle of beam capture	120^{o}
Q-factor of the cavity	10000
Shunt impedance	50 MΩ/m
Pulse repetition rate	12.5 Hz

The obtained distribution of accelerating field along the gaps is shown in the Fig. 4. Growing field in the initial part of the structure and constant field in the following one is achieved with accuracy sufficient for stable dynamics of the high current ion bunches being accelerated.

Octahedral cavity with the diameter of inscribed circle of 1075 mm is an original build-up design (see Fig. 5); it consists of two longitudinal planes and six three-edged sidewalls connected with reliable electrical and thermal junctions.

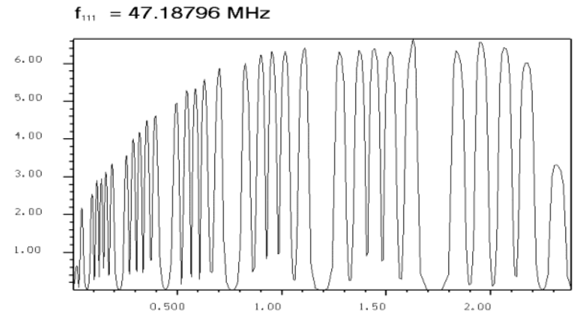

Figure 4: Distribution of the accelerating field along the gaps of the structure.

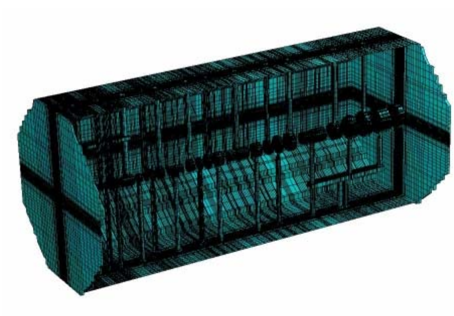

Figure 5: Schematic view of the cavity and PSS-4 accelerating structure.

Mechanical rigidity of the accelerating structure and drift tube arrangement that was constant in time and space was provided with an external steel frame. At the longitudinal beams of the frame, adjusting devices are installed with drift tube rods. The cavity with the accelerating structure is mounted in the vacuum tank on special support adjusting devices with cruciform edge units of the external steel frame.

Figure 6: Photo of the drift tube cases.

Cases of the drift tubes (see Fig. 6) were made of oxygen-free copper at the special precision lathes with diamond tools. Drift tube lengths were 4.6 to 167 mm, drift tube diameters were 22 to 156 mm, and aperture diameter varied from 16 mm initial drift tubes to 30 mm in the rest.

All the units and elements of the accelerating structure were manufactured and assembled; adjustment to the operating resonance frequency and required distribution of the accelerating field in the gaps along the structure are under way. The interior of the accelerating structure in the process of adjustment is shown in the Fig.7.

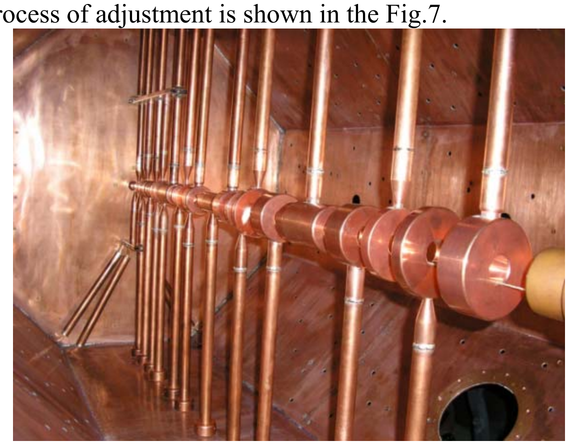

Figure 7: Photo of the internal view of the PSS-4 accelerating structure.

Presently, assembling and adjustment of other systems of the PSS-4 pre-accelerator is being carried out, the injector with ion source of duoplasmatron type, RF power supply system, vacuum system, thermostating system, the system for tracking and diagnostics of the accelerated ion beam, stripping device and deflecting magnet.

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