STAND ADJUSTING OF A NEW PRE-STRIPPING SECTION MILAC

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Results of tuning of irregular interdigital accelerating structure with focusing by radiofrequency field, installation in new prestripping section PSS-4 of the multi charged ions linear accelerator (MILAC), on the experimental stand are presented. The effective inductance-capacitor tuning devices (contrivance) as rods located on the drift tube side, opposite to their holders are developed.

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1. DESIGN FEATURES THE ACCELERATING STRUCTURE PSS-4

The results on development and construction of the prestripping section (A/q = 4) for multi charge 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 [1]. 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 (bunching) phases passing the cells having the phase smaller in absolute value through $\varphi_s = 0$ to the zone of positive (focusing) phases and at last with transition to the zone of negative phases. Such choice of synchronous phases provides the capture of high current ion beam being injected in the phase angle of 120° and maintenance its radial and phase stability along the accelerating structure.

The accelerating structure in which such method of radial and phase focusing of the ion beam bunches is used, is very non-uniform. The requirement of the synchronous phase transfer in a wide range results to that the length трубок drift on each focusing period changes in some times. For this reason tuning of cells of such accelerating structure represents significant difficulties. To this it is necessary to add, that accelerating structure PSS-4 is designed for low entrance energy of ions (30 MeV on a nucleon) and rather high pulse current (12 мA). To provide the maximal capture of particles in a mode of steady radial and longitudinal movement, distribution of an accelerating field in an initial part of structure has been solved to make increasing from a cell to a cell.

2. ADJUSTMENT OF THE ACCELERATING STRUCTURE PSS-4

Interdigital structure represents the large capacitor and inductive loading of the resonator, that results to significant decreasing (almost in 3 times) of the H_{111}-mode resonant frequency. This important feature interdigital type accelerating structure has favourable an effect for the cross sizes of the resonator, that is especially important at creation of heavy ions accelerators, since their rather low speed requires the appropriate increase of a operating wave length. Other important feature of the interdigital type accelerating structure is the ability to retain a π-mode regime, which allows a 2-time increase of accelerating rate in comparison with mode of operations on 2π-mode regime, which is peculiar to structure Alwarez, where E_{010} – mode is used. Such result can be achieved only in the case when execute tuning ensuring uniform distribution of an accelerating field along cells of accelerating structure.

The problem of adjustment accelerating structure PSS-4 was especially difficult in connection with the non-uniform of lengths of cells mention above in structure of the focusing periods and increasing character of distribution of an accelerating field along the accelerator. Therefore it was required to apply a combination of various tuning methods.

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 drift tube holders) were adjusted to the required values.

Table 1. *Main parameters of the PSS-4*

Input ion energy	30 keV/u
Output ion energy	975 keV/u
Operating frequency	47.2 MHz
Growing accelerating field	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°
Q-factor of the cavity	12000
Shunt impedance	50 MΩ/m
Pulse repetition rate	12.5 Hz

In the process of tuning the end resonance device were used which represent quarter wave ending resonant device (inducer); on the side of the inducer 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.

The results of calculations of geometrical and electro-dynamical characteristics are presented in the table 1 and schematic view of the PSS-4 accelerating structure represented on Fig.1.

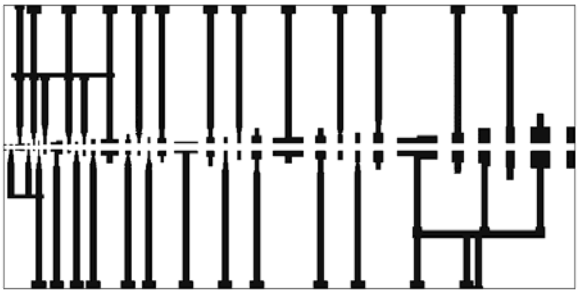

Fig.1. Schematic view of the PSS-4 accelerating structure

External view of the collected resonator with system of cooling is presented on Fig.1, and accelerating structure after initial assembly – on Fig.2.

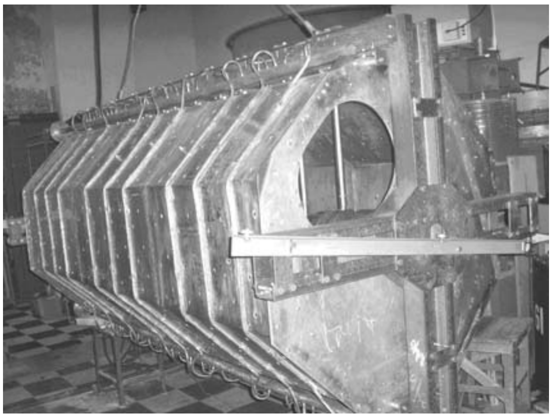

Fig.2. External view of the collected resonator after final technological assembly

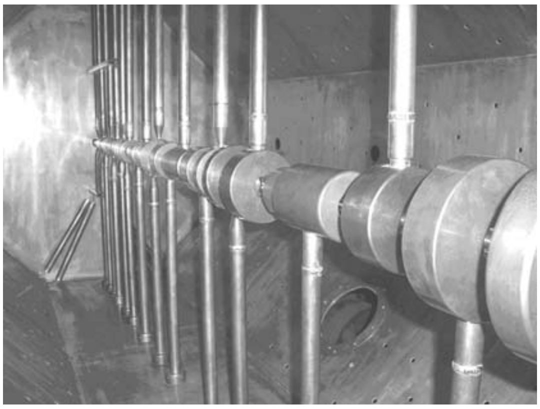

Fig.3. Accelerating structure after initial assembly

As adjusting elements the end resonant tuning elements developed earlier (ERTE) [2], established on the entrance and exit ends of accelerating structure (Fig.4 and Figs.3,5) and two pairs additional current-carrying stems of the drift tubes, established only on its entrance end (Fig.3,5) were used. The physical reasoning of this method of adjustment of the interdigital accelerating structure of basic section MILAC is described in work [3].

Fig.4. The end resonant tuning element on the exit end accelerating structure

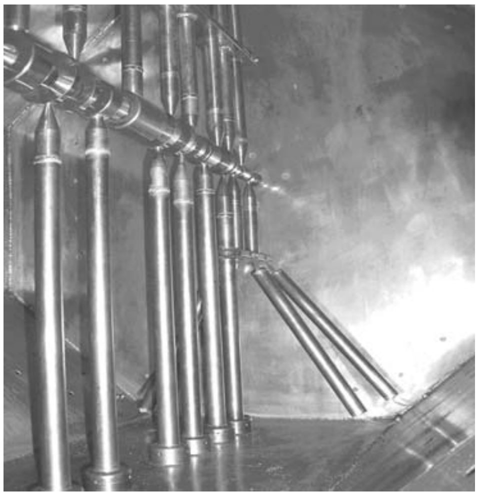

Fig5. The end resonant tuning element and additional stems on the entrance end accelerating structure

3. NEW TUNING ARRANGEMENTS

In the process of manufacturing and assembling the elements of the accelerating structure it appeared that the frequency is higher than the operating frequency by 900 kHz though electric field distribution was close to the calculated one. Therefore development of additional tuning devices was necessary acting on the electric field. The investigations were carried through calculations.

We develop variant extreme simple and effective method of inductance-capacitor tuning. The effect such tuning system on electrical field decrease own frequency of the resonator, that allows once more to reduce a diameter of the resonator and to generate practically uniform accelerating field ensuring the highest rate of acceleration. In this case tuners represent a simple design as rods, located on the drift tube from the side opposite to their holders. They form thus, together with adjacent of drift tube holders additional capacitive and inductive loading, that causes the appropriate decreasing of the own cell frequencies and local increase of an electrical field in gaps between drift tubes. In the present statement such elements of inductance-capacitor loading are named «contrivance».

Their quantity, the sizes (length and diameter) and corners of deviation from a plane which are passing through the basic stems of fastening drift tube, were preliminary defined by numerical simulations, and then checked experimentally at the stand. «Contrivances» have proved as the effective element of tuning locally influencing value of an electric field in the nearest gaps and lowering resonant frequency without noticeable worsening of electrodynamic characteristics of resonant system. On Fig.6 and Fig.7 the constructive decision of fastening «contrivances» on drift tubes is shown, and in the table 2 their sizes and angle of a deviation from a plane which are passing through the basic stems are resulted.

Table 2. *Constructive characteristics and disposition of the «contrivances» on drift tubes*

№	Number drift tube	Diameter, mm	Length, mm	Angle of a deviation, degree
1	16	10	30	0
2	18	15	35	30
3	21	15	33	0
4	23	20	27	0
5	25	10	40	0
6	26	26	30	0
7	28	26	45	45
8	30	26	45	45
9	31	26	70	45

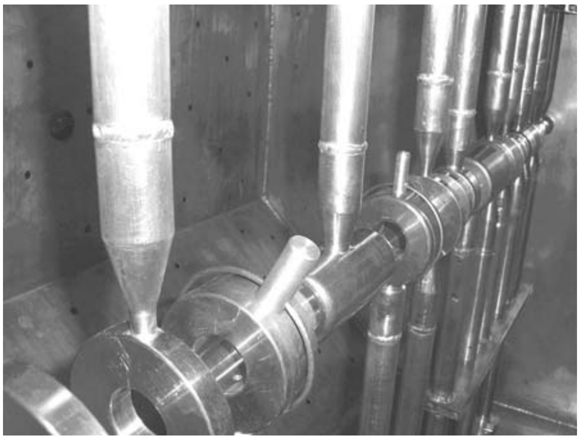

Fig.6. «Contrivance», established on 16 and 18 drift tubes

Fig.7. «Contrivance», established on 26, 28 and 30 drift tubes

As a result of complex influence of all elements of tuning the set distribution of an electric field in structure on operating frequency 47.2 MHz is received. On Fig.8 character of change of an electric field is traced (in relative units) on an axis of the resonator, received at numerical simulations geometry of accelerating structure. Points note values which are set by calculation of dynamics of the accelerated bunch, and by asterisks – experimental values. Deviations of experimental values of electric fields in gaps from calculated values are in acceptable limits.

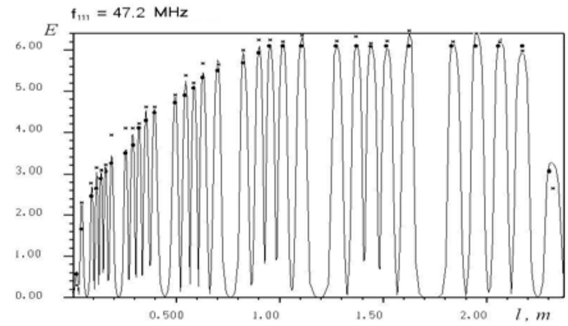

Fig.8. Distribution of the electric field in structure on operating frequency of 47.2 MHz (calculation field set by numerical simulations, • – set by dynamics of a bunch, ∗ – experimental)

On the Fig.9 the accelerating structure after carrying out of final adjustment for the set frequency, and on Fig.10 – process of mounting of the resonator in a vacuum tank is shown.

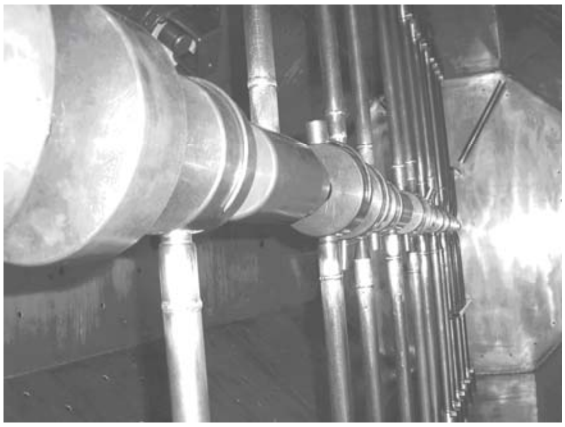

Fig.9. Accelerating structure after final tuning

Fig.10. Mounting of the resonator in a vacuum tank

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СТЕНДОВАЯ НАЛАДКА НОВОЙ ПРЕДОБДИРОЧНОЙ СЕКЦИИ ЛУМЗИ

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Приведены результаты настройки на экспериментальном стенде нерегулярной встречно-штыревой ускоряющей структуры с фокусировкой высокочастотным полем, внедренной в новой предобдирочной секции ПОС-4 линейного ускорителя многозарядных ионов (ЛУМЗИ). Разработаны эффективные настроечные устройства в виде стерженьков, расположенных на боковой поверхности трубок дрейфа противоположно их подвескам.

СТЕНДОВЕ НАЛАДЖЕННЯ НОВОЇ ПЕРЕДОБДИРКОВОЇ СЕКЦІЇ ЛУМЗІ

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Наведено результати настроювання на експериментальному стенді нерегулярної зустрічно-штиревої прискорюючої структури з фокусуванням високочастотним полем, впровадженої в новій передобдирковій секції ПОС-4 лінійного прискорювача багатозарядних іонів (ЛУМЗІ). Розроблено ефективні настроювальні пристрої у вигляді стерженьків, розташованих на боковій поверхні трубок дрейфу протилежно їх підвіскам.