TUNING IRREGULAR INTEDIGITAL ACCELERATING STRUCTURE WITH RF FIELD FOCUSING

V.A. Bomko, A.F. Dyachenko, B.V. Zajtsev, A.F. Kobets, Ye.V. Ivakhno, Z.E. Ptukhina, S.S. Tishkin, E.D. Marynina
NSC KIPT, Kharkov, Ukraine
E-mail: bomko@kipt.kharkov.ua

The results of investigations on tuning the cells of interdigital accelerating structure of a new prestripping section of the multicharge ion linear accelerator (MILAC) are presented in the paper; for this purpose an alternating phase focusing with stepped changing of a synchronous phase is used. In this case, the focusing period consists of a series of cells which lengths vary irregularly due to the synchronous phase change. The procedure of tuning the cells of the accelerating structure to the specified resonant frequency is described, that provides the required electric field distribution between drift tubes. The works were performed by numerical simulations; the results were checked experimentally on test-benches.

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1. INTRODUCTION

To solve some scientific and applied problems, a task of accelerating a high current beam of light ions on the Kharkov multicharge ions linear accelerator MILAC [1, 2] is set. In this connection it is necessary to modernize some accelerator systems especially in its initial part. The existing prestripping section PSS-15 [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) 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) this beam will be output on the acceleration line of the main MILAC section and accelerated up to 8.5 MeV/u.

2. CALCULATION OF CELL LONGITUDINAL DIMENSIONS

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 electrodynamic 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 (see Table 1) 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.

Table 1. *The structure of the focusing period in the construction*

Cell number	Tube length, cm	Synchr. phases, deg.	Tube diameter, cm
0	12,61	-90	22
1	12,62	-90	22
2	36,27	75	22 (26)
3	9,74	50	26
4	6,56	0	31
5	4,59	-65	48
6	12,59	-90	52
7	50,62	75	36 (50)
8	13,71	50	43
9	9,31	0	45
10	10,50	-50	65
11	15,64	-85	62
12	73,48	75	61
13	23,19	60	55
14	9,96	0	60
15	9,22	-65	72
16	33,17	-70	69
17	96,23	75	45 (46)
18	31,97	60	72
19	13,58	0	77
20	14,93	-60	94
21	41,83	-70	87
22	127,75	75	65 (74)
23	42.05	60	88
24	17,58	0	96
25	18,98	-60	110
26	39,44	-90	110
27	167,81	75	69 (85)
28	50,41	60	108
20	48,69	40	129 (140)
30	36,69	0	156
31	78,22	10	156
32	36,21		150

Such arrangement of synchronous phases provides the capture of high current ion beam being injected in the phase angle of 120º and its radial and phase stability

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along the accelerating structure, and gives a possibility to hold the acceleration rate at rather high level.

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.

A LINACV2 computer code was written in FORTRAN90 [5] for calculation of the longitudinal cell dimensions and ion beam dynamics; this code gives a possibility to work in dialogue mode. The geometric sizes of tubes are given in the Table 1.

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 and required accelerating field distribution.

3. CALCULATION OF GEOMETRIC AND ELECTRODYNAMIC CHARACTERISTICS

Calculations of constructive and electrodynamic 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.

The optimization process appeared to be very complicated due to a difference in synchronous phases (as it is seen from the Table 1) 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 electrodynamic characteristics are presented in the Table 2.

The general view of the PSS-4 accelerating structure is given in the Fig.1. The octahedral cavity having the diameter of the inscribed circle 1075 mm is a compound structure consisting of two lengthwise halves connected with safe electrical and thermal contacts.

The most arduous was curried out on determination of the drift tube diameters which should provide the necessary inductive and capacitive characteristics of the cells of the accelerating structure. In the Fig.2 the end section of the accelerating structure with end tuning element is shown.

Table 2. *Geometric and electrodynamic characteristics of the structure*

Input ion energy	30 keV/u
Output ion energy	975 keV/u
Operating frequency	47.2 MHz
Accelerating field	9…85 kV/cm
Total acceleration rate	1.6 MeV/m
Cavity length	239 m
Number of accelerating cells	32
Cavity diameter	107.5 cm
Pulsed current of accelerated ions	10 mA
Angle of beam capture	120°
Q-factor of the cavity	20000
Shunt impedance	150 MΩ/m
Pulse repetition rate	12.5 Hz

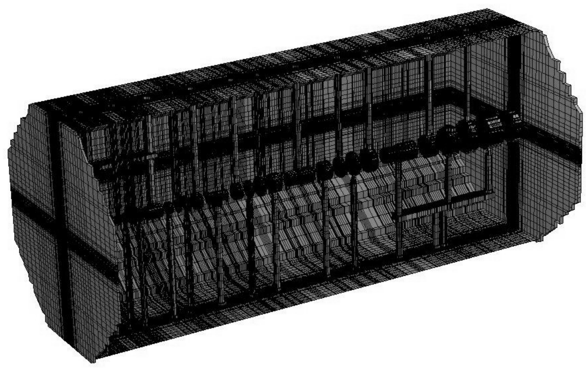

Fig.1.The general view of the PSS-4 accelerating structure

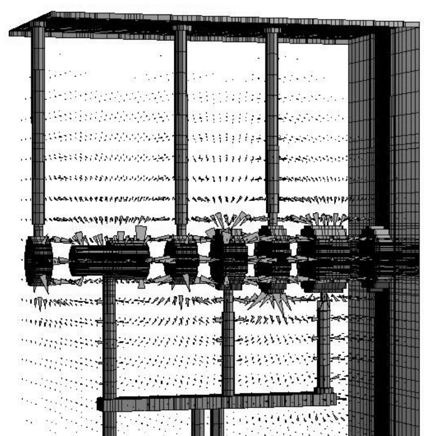

Fig.2. The end section of the accelerating structure with end tuning element

The obtained distribution of accelerating field along the gaps is shown in the Fig.3. 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.

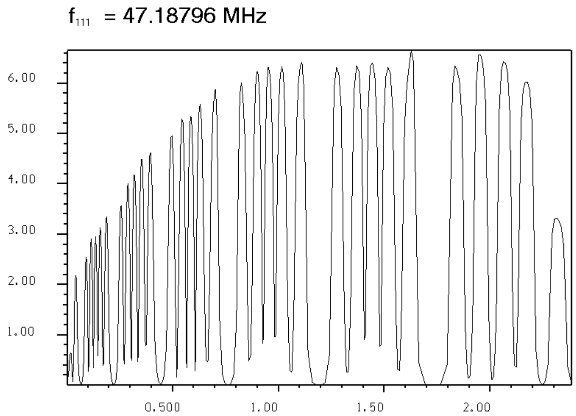

Fig.3. The obtained distribution of accelerating field along the gaps

4. CONCLUSION

By the present time calculations have been completed; technical documentation has been prepared for all the PSS-4 constructive units. According to the Project schedule, manufacture, assembling and adjustment will have been finished by spring of 2006.

REFERENCES

1. V.A. Bomko, A.P. Kobets, Yu.P. Mazalov, B.I. Rudyak. Heavy ion linear accelerator at NSC KIPT // *Ukrainian Physical Journal*, 1998, v.43, №9, p.1144
2. V.A. Bomko, A.F. Dyachenko, A.F. Kobets et al. Interdigital Accelerating H-structure in Multy Charged Ion Linac (MILAC) // *Rev. of Scientific Instruments and Methods*, 1998, v. 69, №10, p.35.
3. V.A. Bomko, B.I. Rudyac, A.F. Kobets et al. Pre-stripping Section of the Multycharged Ion LINAC with A/q =15 // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 1997, №6(6), p.23.
4. V.A. Bomko, A.P. Kobets, B.V. Zaitsev et al. New developments of the ion beams RF- focusing // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations*. 2003, №4(3), p.274-278.
5. V.A. Bomko, A.P. Kobets, Z.E. Ptukhina, S,S, Tishkin. Variant alternation phase focusing with step change of the synchronous phase // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 2004, №2(43), p.153-154.
6. V.A. Bomko, Z.E. Ptukhina, S.S. Tishkin. Variant of the accelerating and focusing structure of the high current linear ion accelerator // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 2006, №8(46), p.100-102.

НАСТРОЙКА НЕРЕГУЛЯРНОЙ ВСТРЕЧНО-ШТЫРЕВОЙ УСКОРЯЮЩЕЙ СТРУКТУРЫ С ФОКУСИРОВКОЙ ВЧ-ПОЛЕМ

В.А. Бомко, А.Ф. Дьяченко, Б.В. Зайцев, А.Ф. Кобец, Е.В. Ивахно, З.Е. Птухина, С.С. Тишкин, Е.Д. Маринина

Приводятся результаты исследований по настройке ячеек встречно-штыревой ускоряющей структуры новой предобдирочной секции линейного ускорителя многозарядных ионов (ЛУМЗИ), в которой применяется переменно-фазовая фокусировка с шаговым изменением синхронной фазы. В этом случае период фокусировки состоит из ячеек, длина которых изменяется нерегулярно. Описана методика настройки ускоряющей структуры на заданную резонансную частоту, обеспечивающая при этом требуемое распределение электрического поля вдоль зазоров. Работы выполнялись путем численного моделирования, результаты которого проверялись на экспериментальном стенде.

НАСТРОЙКА НЕРЕГУЛЯРНОЇ ЗУСТРІЧНО-ШТИРЕВОЇ ПРИСКОРЮЮЧОЇ СТРУКТУРИ З ФОКУСУВАННЯМ ВЧ-ПОЛЕМ

В.О. Бомко, А.Ф. Д'яченко, Б.В. Зайцев, А.П. Кобець, Є.В. Івахно, З.Є. Птухіна, С.С. Тішкін, Е.Д. Мариніна

Приводяться результати досліджень по настройці комірок зустрічно-штирьової прискорюючої структури нової передобдиркової секції лінійного прискорювача багатозарядних іонів (ЛУМЗІ), в якій використовується варіант змінно-фазового фокусування. Прискорююча структура складається із послідовності комірок з дуже нерегулярною довжиною трубок дрейфу. Описана методика настройки таких комірок на робочу частоту і процес формування розподілу прискорюючого поля. Роботи виконувались методом чисельного моделювання, результати перевірялись на експериментальному стенді.