VARIANT OF THE ACCELERATING AND FOCUSING STRUCTURE OF THE HIGH CURRENT LIGHT ION LINEAR ACCELERATOR

V.O. Bomko, Z.O. Ptukhina, S.S. Tishkin
NSC KIPT, Kharkov, Ukraine
E-mail: bomko@kipt.karkov.ua

In the paper, the IH structure for He+ beam with the injection energy of 30 keV/u and A/q=4 is presented. Focusing of He+ beam is performed with the method of alternating phase focusing with the stepped changing synchronous phase along the focusing period. In order to increase the beam capture coefficient into the mode of acceleration the increasing field is applied in the initial part of the structure. The elements of the accelerating structure were calculated with the LINACV2 code; ion beam dynamics was calculated with Poisson Superfish and PARMELA codes.

The limiting accelerated current is 11.5 mA with injection current 60 mA.

PACS: 29.17.+w

1. INTRODUCTION

The conception of the accelerating and focusing structure of the high current He^+ ion accelerator was described in [1]. Its main features: growing field in the initial part of the accelerator, large range of phases, phase amplitude of the synchronous phase up to ±80°, original “stepped” changing synchronous phases along the accelerating and focusing period. Investigations of the He^+ ion beam dynamics were performed for this structure with the LINACV2 code developed by authors; the results were compared with calculations made with PARMELA code. Coincidence of the results was 98%. In the present paper field calculations were made in the structure indicated above with Poisson Superfish code; beam dynamics was investigated with PARMELA code. The goal of the work was testing of calculations of He^+ ion beam dynamics with LINACV2 with results obtained with independent well known and generally recognized codes Poisson Superfish and PARMELA.

2. THE TASK SETTING

The task was to develop a structure for acceleration of H^+ ions to 975 keV/u and designed for output current of the order of 10 mA with injection current of 30 mA; this acceleration structure should be very simple in construction. The operating frequency was 47.2 MHz. The stages of designing were as follows:

1. Selection of the accelerating structure.
2. Selection of the structure for the accelerating and focusing period.
3. Defining the region of the particles capture into acceleration mode.
4. Defining radial stability.

For the given task, the interdigital accelerating structure possessing such advantages as high acceleration rate, low RF-losses and compactness is considered to be the most efficient accelerating structure. The structure of the focusing period in the presented design contains a number of cells where the synchronous phase changes discretely from the negative values (grouping phases) to the positive values (focusing phases) and ends with the transition to the negative phases. The sequence of the synchronous phases is following: -90°, 75°, 60°, 40°, 0°, -60°. Later on, the structure of the focusing period is changed towards increasing the acceleration rate at the cost of raising the number of cells with small absolute value of synchronous phase; that allows us to avoid adding βλ to the length of the transition drift tube Stability of the movement is provided by the growing field in the initial part of the structure. The growing field allows an essential increase in the width and depth of the potential well; this provides a large capture in phases and obtaining the required current. At the same time, in asymmetric and modified APF [2,3] large absolute values of synchronous phases up to ±80° and lengthening the drift tube in each focusing period by βλ are necessary for obtaining the acceptable capture angle and the current being accelerated; such lengthening decreases the acceleration rate.

3. INVESTIGATIONS OF THE ACCELERATION STRUCTURE

As it was mentioned before, the goal of the paper is independent testing calculations of He^+ beam dynamics carried out before with the original code LINACV2 (representing the integrated environment for development the accelerating channel of the linear accelerator taking in consideration space charge forces, and for calculations of beam dynamics) with Poisson Superfish and PARMELA codes. The testing procedure includes the following stages:

1. Calculation of geometric sizes of the structure with LINACV2 code.
2. Calculation He^+ ion beam dynamics with LINACV2 code.
3. Calculation of electric filed distribution with Poisson Superfish code using geometric sizes of the structure obtained at the stage 1.
4. Preparation of the fields obtained with Poisson Superfish to input in PARMELA code.
5. Calculations of He^+ ion beam dynamics with PARMELA code.
6. Comparing the results of dynamics calculations obtained with LINACV2 code and Poisson Superfish + PARMELA codes.

Geometric sizes of the structure are given in Table.

As it is seen from the Table, lengths of drift tubes change strongly along the focusing periods, that is, the structure is sharply nonuniform which makes calculations of electrodynamics characteristics difficult. In Fig.1 a fragment from first 11 accelerating gaps is shown with plotted equipotentials and E_z and E_r components of accelerating field corresponding to this section on the axis of the structure. 64 files calculated with Poisson Superfish code were prepared corresponding to each half-cell of the accelerating periods.

Geometric sizes of the structure

Cell number	Tube length, cm	Gap length, cm	Synchr. phases, deg.
1	0.63059	1.2271	-90
2	3.64742	1.3642	75
3	0.98483	1.4474	60
4	0.66060	1.5828	0
5	0.46509	1.6949	-60
6	1.28325	1.7367	-90
7	5.14370	1.9267	75
8	1.38668	2.0416	50
9	0.93119	2.2244	0
10	1.04727	2.4158	-50
11	1.55574	2.5119	-85
12	7.28271	2.7604	75
13	2.29041	2.8892	60
14	0.97752	3.0910	0
15	0.90233	3.2824	-65
16	3.23503	3.4294	-70
17	9.35422	3.7256	75
18	3.09407	3.8785	60
19	1.31032	4.1287	0
20	1.44299	4.3855	-60
21	4.05584	4.5713	-70
22	12.35579	4.8741	75
23	4.05248	5.0362	60
24	1.69751	5.3032	0
25	1.83847	5.5719	-60
26	3.82713	5.6750	-90
27	16.30619	5.8878	75
28	4.90091	6.0529	60
29	4.74850	6.3196	40
30	3.58201	6.6700	0
31	2.29544	6.9435	-60
32	7.91049	7.1667	-50

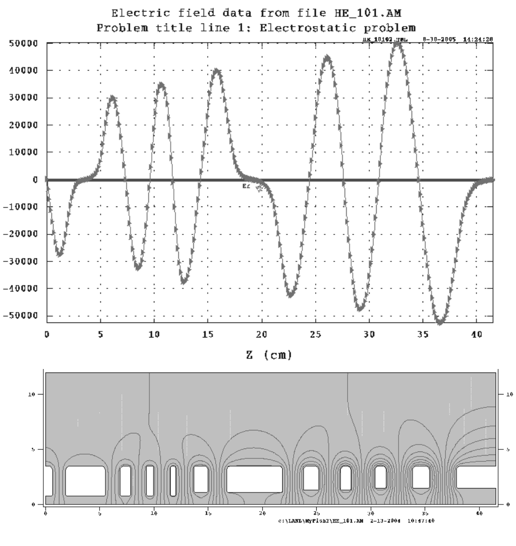

Fig.1. Schematic fragment of the accelerating structure: First 11 gaps and corresponding longitudinal component of the electric field on the axis

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 Fig.2 results of simulations of He^+ ion beam dynamics calculated with LINACV2 in the fields and in the structure with input injection current of 60 mA.

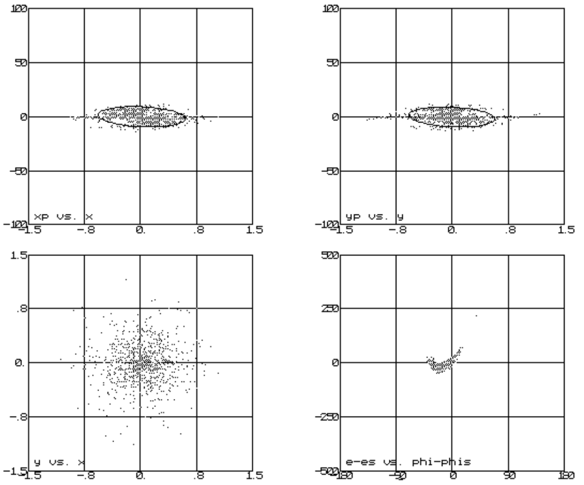

Fig.2. Radial phase portrait and output parameters of the beam at the accelerator output (LINACV2), number of macroparticles is 10 000, input current is 60 mA, output current is 14.0 mA

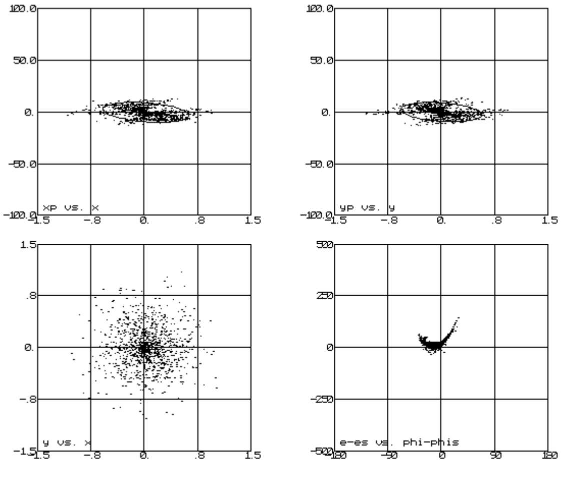

Fig.3 Radial phase portrait and output parameters of the beam at the accelerator output calculated with Poisson Superfish (Fig.1), number of macroparticles is 10 000, input current is 60 mA, output current is 11.5 mA

The coeficient of beam capture into acceleration mode for simulation with LINACV2 with injection current of 60 mA is 32%, and in the fields calculated with Poisson Superfish is 20.8%.

In Fig.4 dependence of output current on injection current is presented.

As it is seen from Fig.4 with the injection current from 0-30 mA practically the same dependence is observed of the accelerated current on injection current.

With the injection current of 60 mA discrepancy between values of output current calculated with the two codes is no more than 14%.

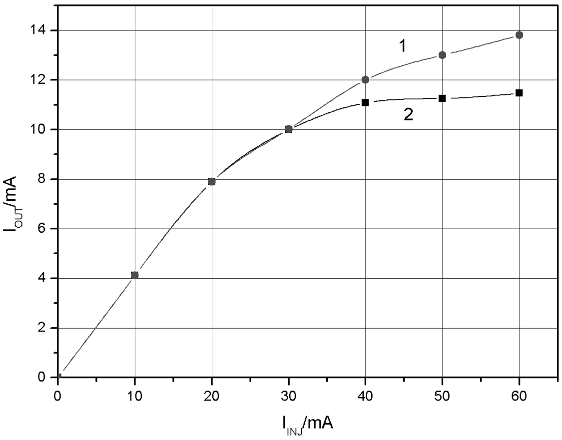

Fig.4. Output beam current after 32 accelerating gaps:
1 – simulated with LINACV2;
2 – with Poisson Superfish

4. CONCLUSIONS

1. Calculation of the accelerating structure and simulating dynamics of He^+ ion beam carried out on the integrated environment LINACV2 developed in NSC KIPT demonstrated good agreement with results of simulations of beam dynamics with generally recognized codes Poisson Superfish and PARMELA.

2. He^+ ion beam dynamics in the structure calculated according to the method described in [1] possesses sufficient stability to random errors of the accelerating and focusing channel which is not usual for accelerators with APF references.

REFERENCES

1. V.O. Bomko, A.P. Kobets, Z.E. Ptukhina, S.S. Tishkin. Variant of alternation phase focusing with stepped change of the synchronous phase // *Problems of Atomic Science and Technology. Series: Nuclear Physics Investigations.* 2004, №2(43), p.153-154.
2. I.D. Dreval, V.V. Kushin. About numerical simulation particle motion in the accelerator with asymmetric alternating phase focusing // *Journal of Techn. Phys.* 1972, v.42, №9, p.1915-1920.
3. V.G. Papkovich, M.A. Khyzhniak, M.G. Shulika. Alternating phase focusing in linear accelerators // *Problems of Atomic Science and Technology. Series: Techn. of Phys. Experiments.* 1978, №2(2), p.51-56.

ВАРИАНТ УСКОРЯЮЩЕ-ФОКУСИРУЮЩЕЙ СТРУКТУРЫ СИЛЬНОТОЧНОГО ЛИНЕЙНОГО УСКОРИТЕЛЯ ЛЕГКИХ ИОНОВ

В.А. Бомко, З.Е. Птухина, С.С. Тишкин

Представлена ускоряющая IH-структура для пучка ионов He^+ с энергией инжекции 30 кэВ/нукл. и A/q=4. Фокусировка пучка He^+ осуществляется методом переменно-фазовой фокусировки в варианте шагового изменения синхронной фазы вдоль фокусирующего периода. Для увеличения коэффициента захвата пучка в режим ускорения в начальной части структуры применяется нарастающее поле. Выполнен расчет элементов ускоряющей структуры по программе LINACV2 и динамики пучка ускоряемых ионов по программам Poisson Superfish и PARMELA. Предельный ускоряемый ток равен 11,5 мА при токе инжекции 60 мА.

ВАРІАНТ ПРИСКОРЮЮЧОЇ ТА ФОКУСУЮЧОЇ СТРУКТУРИ СИЛЬНОСТРУМОВОГО ЛІНІЙНОГО ПРИСКОРЮВАЧА ЛЕГКИХ ІОНІВ

В.О. Бомко, З.О. Птухіна, С.С. Тішкін

У статті презентовано прискорюючу IH-структуру для пучка іонів He^+ з енергією інжекції 30 кеВ/нукл. і A/q=4. Фокусування пучка He^+ здійснюється за методом змінно-фазового фокусування у варіанті покрокової зміни синхронної фази уздовж фокусуючого періоду. Щоб збільшити коефіцієнт захоплення пучка у режим прискорення, у початковій частині структури застосовується поле, яке нарощується. Виконано розрахунки елементів прискорюючої структури за програмою LINACV2 та динаміки пучка за програмами Poisson Superfish і PARMELA. Межа струму, що прискорюється, дорівнює 11,5 мА, якщо інжектовано струм 60 мА.