VARIANT OF ALTERNATING PHASE FOCUSING WITH THE STEPPED CHANGE OF THE SYNCHRONOUS PHASE

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In the paper the calculation of the accelerating structure with the stepped change of the synchronous phase is presented. The method is tested for the calculation of the accelerating structure and He^+ beam with A/q=4 in the energy range from 30 keV/n to 0.975 MeV/n.

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1. INTRODUCTION

The alternating-phase focusing (APF) of ion beams in linear accelerators since the moment of its discovery [1,2] has passed several stages of improvement until it has reached characteristics sufficient to its high competitiveness in modern accelerating structures. However, the main drawbacks of the traditional APF – the low acceleration rate, the low limit current of ions being accelerated - are to be improved.

The structure of a focusing period in the method of stepped change of the synchronous phase (SCP) contains a number of cells where the synchronous phase in the cells changes in the stepped manner from the negative values (bunching phase) to the synchronous phase less in absolute value and φ_s=0, to the region of positive (focusing) phases and ends in the transition to negative values. This phase variation in the center of gaps between cells gives a possibility to 'capture' the region of the strong bunching and focusing, to ensure the high acceleration rate and to provide, together with the increasing field, the high coefficient of beam capture. The calculation of the accelerating and focusing channel was carried out with taking into account the repulsing Coulomb forces in the fields created with the actual drift tube configuration.

2. THE INVESTIGATION OF THE BEAM DYNAMICS IN THE APF WITH SCP STRUCTURE

In the present paper the calculation of electrostatic fields was carried out with the method of auxiliary charges [3]. A program for realization of the method was proposed which allowed us to perform the calculation in the dialog regime. The accelerating and focusing period consists of the cells with synchronous phase of –90°, 75°, 60°, 40°, 0°, -60°. The aperture radius was changed from 0.75 cm to 1.5 cm, the maximum electric field strength was changed from 25 kV/cm to 75 kV/cm. The length of the accelerating structure was 237.7 cm. The simulation of He^+ beam dynamics was carried out with LINACV2 code by the authors of the present paper and the results were compared with the results of dynamics simulation with the PARMELA code. Coincidence is 98.0%. The number of large particles is 10 000. In Fig.1 the projection of the input emittance and geometric sizes of He^+ beam are shown.

The SCP method allows us to increase the particle acceleration rate in comparison with the known APF versions where at both bunching sections and sections

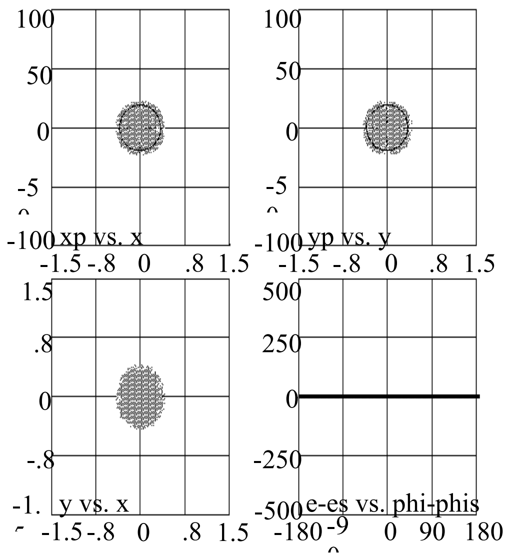

Fig.1. Projections of the input emittance and geometric sizes of the He^+ beam

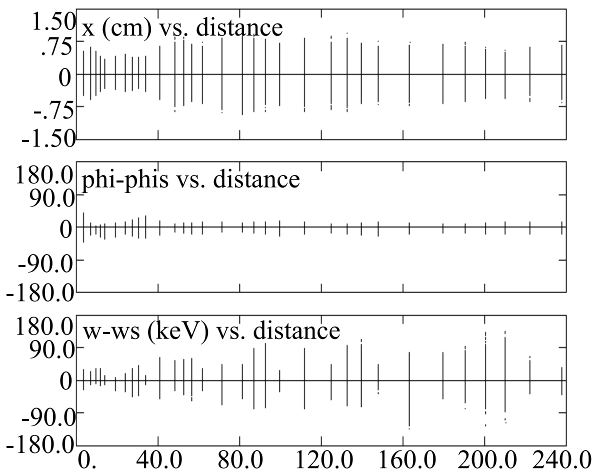

Fig.2. The amplitude of radial and longitudinal oscillations and the energy spread of the ion bunch along the structure

of radial focusing, the synchronous phase is constant and large in absolute value. This is aided, from one hand, with the fact that the focusing period contains the gaps with synchronous phases, which are low by the absolute value, and from the other– comparatively small step in changing of φ_s along the focusing period does not require an insertion $\beta\lambda$ in length to change the bunch center from positive synchronous phases to negative ones.

Such increasing of the acceleration rate is reached, from one hand, with the fact that the SCP focusing period contains the gaps with synchronous phases, which are low in absolute value. From the other hand the comparatively small step in changing of φ_s along the focusing period does not require an insertion $\beta\lambda$ in length to change the bunch center from positive synchronous phases to negative ones.

The drawback of accelerating structures with APF is the dependence of the focusing force on the phase of particle transit to the accelerating and focusing structure. At the same time, the SCP provides a transverse and longitudinal stability of the particle bunch as the value of cosine of the phase advance of the particle radial oscillations with taking into account their phase movement is in the region of stability. In Fig.3 the output beam parameters are given with the zero injection current. In the structure calculated by the APF SCP method, the rise of the transverse emittance of He^+ of 96% was observed with the zero injection current and input phase length of the beam of 150º. This rise in the emittance is inherent for APF linacs with large capture angles without the preliminary bunch focusing. The rise in the emittance of the central part of the bunch (±20º) was not observed.

The dependence of the output particle current on the injected current was studied (Fig.4). In the injected beam a random filling of 4-D transverse phase volume was supposed.

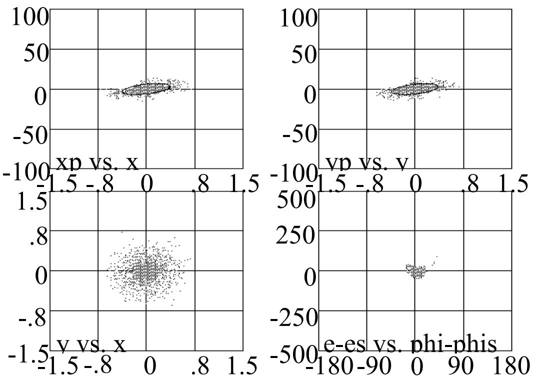

Fig.3. Output beam parameters with the zero current

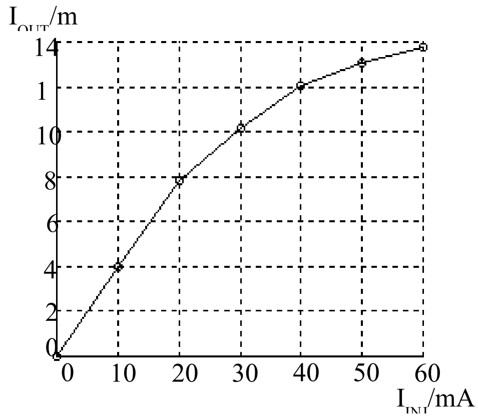

Fig.4. Accelerated current as a function of injection current

In the Table the main parameters of the accelerating structure are presented.

Operating frequency, MHz	47,2
Injection energy, keV/n	30
Output energy, MeV/n	0,975
Number of accelerating cells	32
Total length, cm	237,7
Electric field at the electrodes, kV/cm	25...75
Maximum electric field, kV/cm	170
Aperture radius, cm	0,75...1,5
Normalized transverse acceptance, π mm mrad	1,0
Input emittance 90%, π mm mrad	0,59
Rise in normalized emittance with zero current, %	96
Beam capture coefficient with the injection current of 0 mA, % 60 mA, %	42 23
Current limit, mA	13,7

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ВАРИАНТ ПЕРЕМЕННО-ФАЗОВОЙ ФОКУСИРОВКИ С ШАГОВЫМ ИЗМЕНЕНИЕМ СИНХРОННОЙ ФАЗЫ

В.А.Бомко, А.Ф.Кобец, З.Е.Птухина, С.С.Тишкин

В работе предлагается расчет ускоряющей структуры с шаговым изменением синхронной фазы. Метод апробирован на расчете ускоряющей структуры и динамики пучка ионов He^+ с A/q=4 в диапазоне энергий 30 кэВ/н...0.975 МэВ/н.

ВАРІАНТ ЗМІННО-ФАЗОВОГО ФОКУСУВАННЯ ІЗ ПОКРОКОВИМ ЗМІНЕННЯМ СИНХРОННОЇ ФАЗИ

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В роботі запропонований розрахунок прискорюючої структури із покроковим зміненням синхронної фази. Метод апробовано на розрахунку прискорюючої структури і динаміки пучка іонів He^+ з A/q=4 в інтервалі енергій 30 кеВ/н...0.975 МеВ/н.