INDUCTANCE-CAPACITOR SYSTEM FOR TUNING OF INTERDIGITAL STRUCTURE OF THE ION LINEAR ACCELERATOR

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The task of tunning of the Interdigital H-structure contain in ensuring uniform distribution of an accelerating field and alignment of design resonant frequency. Calculations of constructive and electrodynamics characteristics and tunning procedure of the accelerating structure for the new MILAC prestripping section (PSS-4) are discussion. The effective inductance-capacitor tuning devices (contrivance) as rods located on the drift tube side, opposite to their holders are developed. It is shown, that the adjusting of interdigital accelerating structure can be carried out with the help only by this simple and effective tuning of system.

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1. INTRODUCTION

The interdigital type accelerating structure takes the dates from middle fifties [1, 2]. Lately it widely used for creation of heavy ion linear accelerators. This structure is based on a principle of excitation in the cylindrical resonator of an H_{111} - mode, which characteristics is the presence of a longitudinal magnetic and cross electrical field. When interdigital system with drift tubes located along resonator the longitudinal component of electrical field appears in gaps between drift tubes which is used for acceleration of the charged particles.

Such 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 wavelengs. Other important feature of the interdigital type accelerating structure is the ability to retain 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.

When the resonator is loaded by interdigital accelerating structure an essential difference of own cell frequency takes place depending on their length. In rather long resonators designed for a gain of speed accelerating ions in 2 - 3 times, the relative increase of own frequency of cells on the entrance and exit end of the accelerator can make $30 - 50$ percents. The task of tuning contain in ensuring quasyuniform distribution of an accelerating field along accelerating structure, consists not only in alignment of frequencies, but also in compensation of fall of a field level on the structure ends of the resonator peculiar to H - structures. For this reason, effective tuning systems and combination of tuning devices required, which will allow to compensate the appointed deviation and to achieve thus of the required working frequency.

2. METHODS OF TUNING OF INTERDIGITAL ACCELERATING STRUCTURES

During development and creation of interdigital accelerating structures at the various accelerating centres were developed the their own methods and devices of the tuning. By the way of their impact on accelerating field distribution tuning systems are subdivided on inductive, capacitor and resonant. In structures of a drift tube comb type the constant difference of potentials between drift tubes take place, thus an accelerating field value falls with growth of cell length of structure and accordingly acceleration rate decrease. The tuning in this case does not play an essential role. On such principle the heavy ion linear accelerator is constructed in laboratory of Munich [3]. More perfect accelerating structure is constructed in prestriping part of UNILAC GSI [4] where the formation of an accelerating field is carried out with the help of inducers. Reasonable high acceleration rate in this case is achieved by division of accelerating structure into sections in which the difference

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of potentials is increased with growth of lengths of accelerating cells.

An effective method was developed for adjusting the cells of the accelerating structure Kharkov MILAC poststriper using additional current-carrying rods located at an angle to the supporting rod (Fig.1). This method of tuning the inductive accelerating cell parameters allowed formation of a uniform accelerating field distribution along the structure. This allowed to increase significantly the acceleration rate. Additionally, a method was developed for adjusting the field distribution using the ending resonance adjusting device (ERAD). Thus, the main section $11.25\,m$ in length with 39 drift tubes, of which 19 contain magnetic quadrupoles gives a possibility to accelerate ions with $A/q \leq 5$ at the frequency of $47.2\,MHz$ from 0.975 to $8.5\,MeV/u$. Total acceleration rate in the main section is $3.2\,MeV/m$.

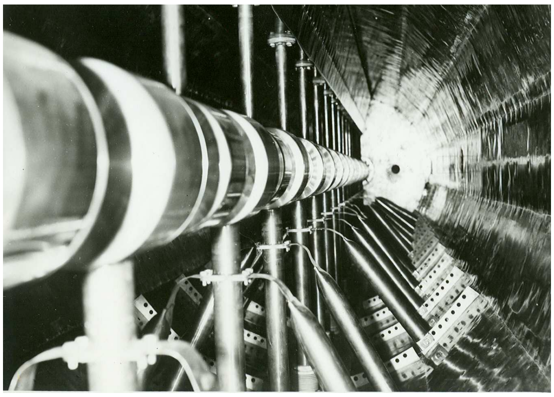

Fig.1. *Accelerating structure Kharkov MILAC poststriper*

3. DESIGN FEATURES THE ACCELERATING STRUCTURE PSS-4

Development and construction of the new prestripping section 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 using the method of alternating phase focusing with stepped changing the synchronous phase along the focusing period. 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 $\varphi_s = 0$ 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 120^0 and its radial and phase stability along the accelerating structure, and gives a possibility to hold the acceleration rate at rather high level. 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 of the structure parameters (cavity diameter, cavity shape, the drift tube diameters, diameters of the drift tube holders) were adjusted to the required values.

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 and schematic view of the PSS-4 accelerating structure - on Fig.2.

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 sm
Pulsed current of accelerated ions	12 mA
Angle of beam capture	120^0
Q-factor of the cavity	12000
Shunt impedance	50 MΩ/m
Pulse repetition rate	12.5 Hz

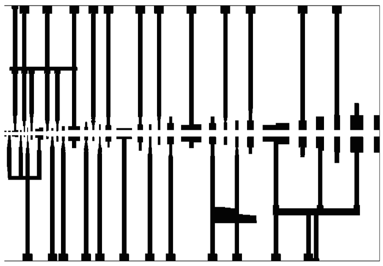

Fig.2. *Schematic view of the PSS-4 accelerating structure*

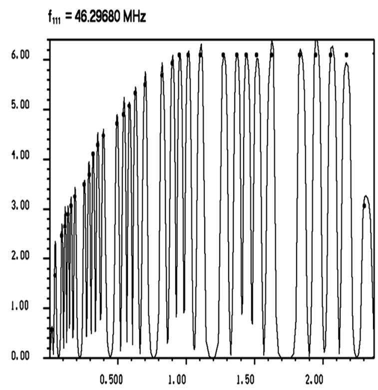

Fig.3. *Distribution accelerating field in PSS-4*

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 take as increasing from cells to cells in order to provide the maximum capture of particles in a mode of stable longitudinal motion. In this case the width and depth of the potential well in which the particles moved increases significantly. The obtained distribution of accelerating field along the gaps is shown on 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.

4. ADDITIONAL TUNING DEVICE

In the process of manufacturing and assembling the elements of the accelerating structure $PSS-4$ 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".

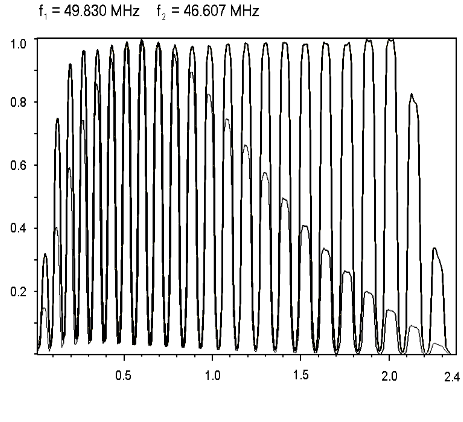

Fig.4. *Distribution of an electrical field in gaps: a) initial; b) uniform field*

The approbation of a tuning method with an inductance-capacitor type devices in view of the contrivances was executed on another structure designed for acceleration of heavy ions from energy $220\,keV/u$ up to $1000\,keV/u$ at working frequencies $47,2\,MGz$. Fig.4 represented distribution of an electrical field in gaps: a) initial and b) uniform field received as a result of tuning with help only of the contrivance. From a Fig.4 it is possible to see, that for compensation of the strongly deformed distribution of a field caused by fall of capacitor loading with increase of gap length between drift tubes of a constant diameter, it was required to establish some of contrivances on second half of structure.

The described inductance-capacitor system was successfully applied for additional tuning of accelerating structure PSS-4. Thus the dismantle of drift tubes was not required. Additional tuning devices are established with the help of spring contacts on a lateral wall several of drift tubes. In result by selection of length contrivance and corner of their installation concerning a plane of an arrangement of accelerating structure the required distribution of an accelerating field and calculated frequency of the resonator was received. In a Fig.5 the internal view of the resonator PSS-4 is given.

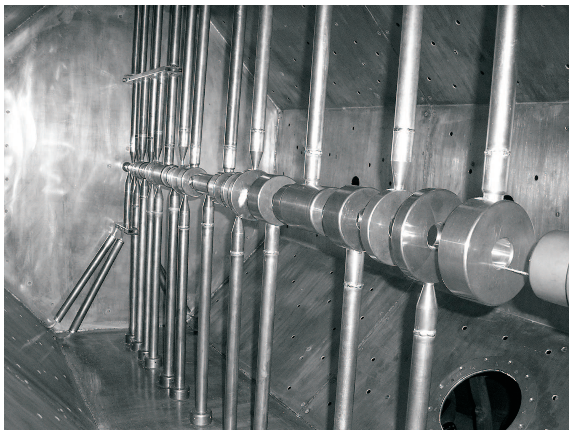

Fig.5. *PSS-4 accelerating structure*

5. CONCLUSION

The new effective inductance-capacitor tuning devices (contrivance) as rods located on the drift tube side, opposite to their holders are developed. At the certain design the exact local tuning of cells is possible for carrying out not only selection of contrivance length, but also by change of a corner of their disposition concerning an axis of drift tube holders. The high efficiency such inductance-capacitor tuning system allows to receive required electro-dynamic characteristics of accelerating structure at an identical small diameter of drift tubes, that considerably simplifies their design, reduces a radiating background around of the accelerator and prevents occurrence of the multypaction high-frequency discharges.

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ИНДУКТИВНО-ЕМКОСТНАЯ СИСТЕМА НАСТРОЙКИ ВСТРЕЧНО-ШТЫРЕВОЙ СТРУКТУРЫ ЛИНЕЙНОГО УСКОРИТЕЛЯ ИОНОВ

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Задачей настройки встречно-штыревой ускоряющей структуры, возбуждаемой на H_{111} волне, является получение требуемой величины резонансной частоты и получение равномерного распределения ускоряющего поля вдоль зазоров между трубками дрейфа. Приводятся результаты разработки новой индуктивно-емкостной настроечной системы в виде штырей, располагаемых конструктивно на боковой стенке трубок дрейфа, противоположно несущим подвескам. Описан процесс формирования с их помощью расчетного распределения ускоряющего поля в нерегулярной структуре сооружаемого нового ускорителя легких ионов ПОС - 4, рассчитанного на энергию ускоренных ионов 1 МэВ/нуклон.

ІНДУКТИВНО-ЄМКІСНА СИСТЕМА НАСТРОЙКИ СТРІЧНО-ШТИРЬОВОЇ СТРУКТУРИ ЛІНІЙНОГО ПРИСКОРЮВАЧА ІОНІВ

В.О. Бомко, А.Ф. Дъяченко, Б.В. Зайцев, А.П. Кобець, Е.В. Івахно, К.В. Павлій, Я.Н. Феденьова, С.Н. Дубнюк, С.С. Тішкін, З.О. Птухіна

Завданням настройки стрічно-штирьової прискорюючої структури, що збуджується на H_{111} хвилі, є отримання необхідної резонансної частоти і отримання рівномірного розподілу прискорюючого поля уздовж зазорів між трубками дрейфу. Наводяться результати розробки нової індуктивно-ємкісної настроювальної системи у вигляді штирів, що розташовуються конструктивно на бічній стінці трубок дрейфу, протилежно несучим підвіскам. Описаний процес формування з їх допомогою розрахункового розподілу прискорюючого поля в нерегулярній структурі споруджуваного нового прискорювача легких іонів ПОС-4, розрахованого на енергію прискорених іонів 1 МеВ/нуклон.