ELECTRODYNAMIC CHARACTERISTICS OF HIGH CURRENT IH-ACCELERATING STRUCTURE

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Development of the IH-resonators needs careful adjustment of the accelerating field distribution inside the structure because it is closely related to the beam dynamics. There are presented results of the numerical modeling such resonators for low beta velocities. Two methods of the field optimization were explored: by changing the end cell geometry and by changing the geometry of the pilons.

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INTRODUCTION

Interdigital H-accelerating resonators are well established in the field of low beta proton acceleration. Thus this structure was chosen under the BWLAP project for proton acceleration in the beam velocity range: $0.01 \le \beta \le 0.03$. Investigated resonator (Fig. 1) consists of drift tubes, stems and vanes.

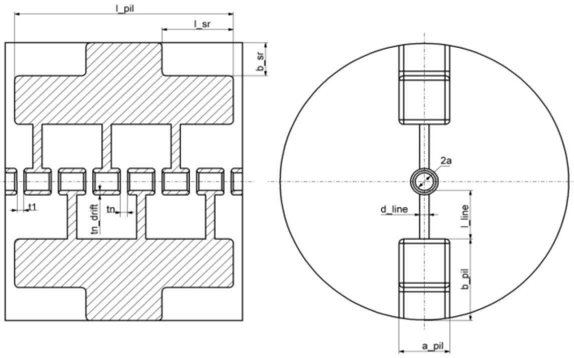

Fig. 1. IH-Tank layout

As for all IH structures working at π mode, period D is equal to:

$$D = \frac{\beta\lambda}{2}. \qquad (1)$$

Two operating frequencies: 144 and 433 MHz were chosen according to the frequency of the main accelerator (1300 MHz). It is third (433 MHz) and ninth (144 MHz) sub harmonics.

1. ONE PERIOD MODELLING

Firstly investigations were performed at one geometric period (Fig. 2) which includes two electric periods.

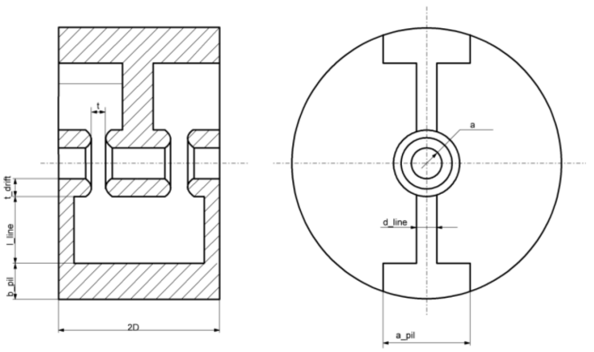

Fig. 2. One period layout

Two magnetic boundary planes were used at the opposite sides of the model to create correct field distribution. In IH-resonators electric field concentrates between drift tubes in opposite directions in neighboring gaps. Magnetic field also directed along the beam axis but it is suited at the opposite sides of the stems.

At the center of drift tubes there is a lack of electric field and presence of the longitudinal component of magnetic field. Thus it would be the best place to locate magnetic boundary plane. Also one magnetic symmetry plane (belonging to the axis of the stems) was used to increase the accuracy.

At this stage of the modelling IH-resonator demonstrated high values of effective shunt impedance: from 300 to 450 MOhm/m for different frequencies, particle velocities, aperture radii, accelerating gaps and geometric sizes of the stems and pilons. It should be noted that for this beam velocity range better to use lower frequency since it's got higher wavelength and higher period value. For example in case of the 433 MHz and $\beta = 0.01$ period D is equal to 3.5 mm. Such design couldn't be practically realized and they were not taken into further consideration.

2. FULL STRUCTURE MODELLING

2.1. END CELLS MODIFICATIONS

After structure adjustment at one geometric period full tank (see Fig. 1) was simulated. But the field inside whole resonator isn't the same as inside one period. There is a difference of the magnetic field distribution at the central part of the resonator and at the end part of resonator. At the central part magnetic field has longitudinal component as in case with one period. At the end parts magnetic field turns around the pilon. It leads to the different field distribution, different working frequency of the end circuits (comparing to the central part of the structure). As a result we have irregular electric field distribution along the beam axis and low efficiency of the resonator. At this stage optimizing of the electric field distribution was main goal. To characterize the irregularity special coefficient was introduced:

$$K_{ir} = \frac{E_{\max} - E_{\min}}{E_{\max}} \cdot 100\%. \qquad (2)$$

The models with 7, and 9 accelerating gaps were simulated. Firstly all researches were performed with operating frequency equal to 352 MHz. Such structures have higher period value (comparing to the 433 MHz version) and lower geometric sizes (comparing to the 144 MHz version). For initial investigations it was best choice between simulation time and possibility of changing geometry of the structure.

At the beginning there were not any recesses in the vanes (as one can see on Fig. 1). There were only gaps between end wall of resonator and pilons to make a closed flux of magnetic field around pilon. From the Table 1 we can see that structure without recesses in the vanes has worst irregularity. Also applying the recess in the pilons didn't improve the irregularity significantly.

Table 1

Dependence of the field irregularity from vanes modifications

Type of modifications	K_{ir},%
Without modifications	63
Changing the gap between pilon and end wall (best of all)	60
Using rectangular pilon recess (best of all)	53

The next step of optimization was modification of the end cell geometry. Firstly the thickness of the end cells placed on the end wall of the resonator was changed. As a result the irregularity became better: 39%. Secondly the thickness of the two nearest end cells and the gap between them was changed. Employment these methods decrease the irregularity till 11%. Our main goal was noticeable field increasing at the end accelerating gaps and soft field increasing at neighbor gaps. It was realized using end cells geometry described at the Fig. 3.

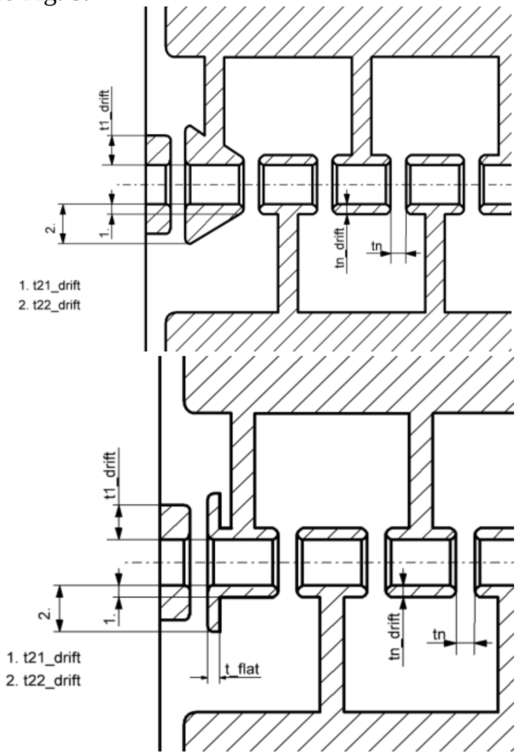

Fig. 3. Different types of end cells modifications

As a result irregularity is equal to 5 % with the field distribution showed at the Fig. 4.

Last but not least the structure was optimized for two main operating frequencies: 144 and 433 MHz. All techniques of end cell modifications were performed for both frequencies. The irregularity became better than 5% for 144 MHz resonator and ~13% for 433 MHz resonator. Both resonators have the same aperture inner diameter (a=10 mm), same particle velocity ($\beta = 0.04$) and same number of accelerating gaps (9).

All of these techniques make irregularity better but they have a negative influence on the effective shunt impedance value: without modifications it was equal to 250 MOhm/m; after using all this techniques it became 130 MOhm/m. But it should be mentioned that increasing the amount of periods inside the tank makes the value of shunt impedance (reduced) a little bit higher.

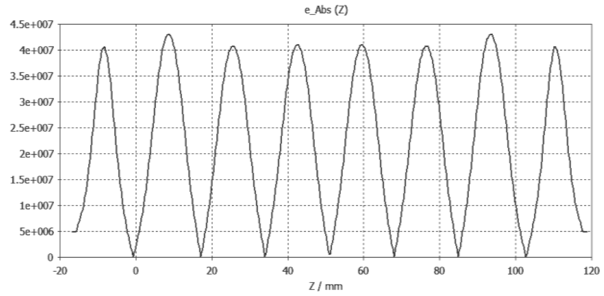

Fig. 4. Electric field profile after end cell modifications

2.2. PILON MODIFICATION

Next stage of the field distribution optimization became a pilon modification. This time rectangular pilon recess wasn't used. Field distribution adjustment was performed by using holes in the pilons [2]. The optimal geometry is shown at the Fig. 5.

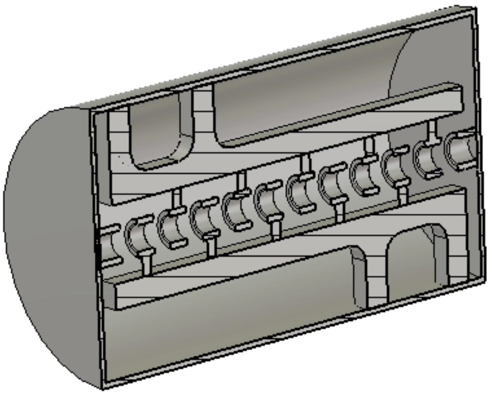

Fig. 5. Field adjustment by using holes in the pilons. $f = 144\,MHz,\ \beta = 0.03$

Electrodynamic parameters of this structure are presented in the Table 2. It shows that this structure has best values of shunt impedance and irregularity coefficient.

Table 2

Electrodynamic characteristics of the IH resonator with holes in pilons

Particle velocity $\beta(v/c)$	0.03
f, MHz	144
Period D, mm	31
Acceleration gap t, mm	15.5
R_{sheff} , MOhm/m	200
K_{ir},%	5

For this geometry of the IH resonator beam dynamics modeling was performed. Beam phase plots are shown at the Fig. 6 for accelerating gradient $E_0 = 1$ MV/m.

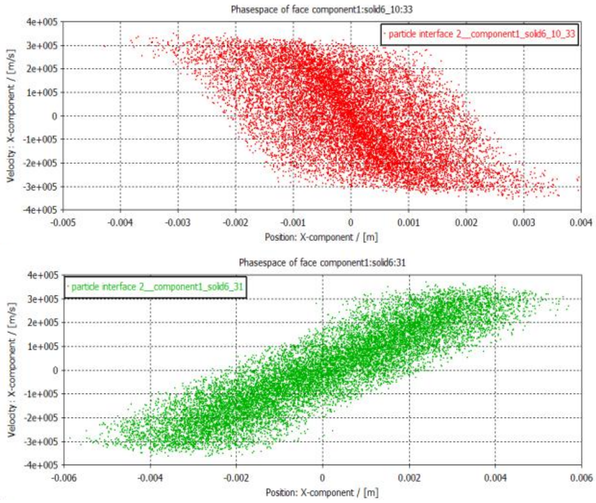

Fig. 6. Beam phase plots (x, x') at the beginning (top) and at the end of the structure (bottom)

CONCLUSIONS

In this article the adjustment of IH-structure for low beta acceleration was presented. Two methods of the field optimization were explored: by changing the end cell geometry and by changing the geometry of the pilons. Best results of electrodynamic parameters were obtained in the case with working frequency 144 MHz and with holes inside the pilons.

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ЭЛЕКТРОДИНАМИЧЕСКИЕ ХАРАКТЕРИСТИКИ IH-РЕЗОНАТОРА ДЛЯ УСКОРЕНИЯ СИЛЬНОТОЧНЫХ ПУЧКОВ

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Разработка и оптимизация встречноштыревых резонаторов требует тщательной настройки распределения ускоряющего поля вдоль оси пролета пучка, поскольку оно существенно влияет на динамику ускоряемых частиц. Представлены результаты численного моделирования такой структуры для низкоэнергетического диапазона частиц. Исследованы два метода настройки распределения ускоряющего поля: путем изменения геометрии конечных ячеек и с помощью изменения геометрии пилонов.

ЕЛЕКТРОДИНАМІЧНІ ХАРАКТЕРИСТИКИ IH-РЕЗОНАТОРА ДЛЯ ПРИСКОРЕННЯ ПОТУЖНОСТРУМОВИХ ПУЧКІВ

С.Є. Топорков, М.В. Лалаян, А.А. Калашнікова

Розробка та оптимізація зустрічноштирьових резонаторів вимагає ретельного настроювання розподілу прискорюючого поля уздовж осі прольоту пучка, оскільки воно істотно впливає на динаміку прискорених частинок. Представлено результати чисельного моделювання такої структури для низькоенергетичного діапазону часток. Досліджено два методи налаштування розподілу прискорюючого поля: шляхом зміни геометрії кінцевих комірок і за допомогою зміни геометрії пілонів.