TUNING METHOD FOR THE ACCELERATING STRUCTURE WITH RFQ FOCUSING AND INCREASING VOLTAGE

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Abstract

RF voltages across the accelerating and focusing gaps in the accelerating section with spatial periodic RFQ focusing (SPRFQF) are equal [1]. It is possible to maintain the constancy of RF voltages across the focusing gaps and to increase the RF voltage across the accelerating gaps [2]. It widens the range of the RFQ linac applicability, and complicates the tuning of the structure with SPRFQF in many respects. The necessary tuning method is eleborated at IHEP. It is presented in the poster. The full-scale model of the accelerating section is tuned. Some results and peculiarities of the tuning are discussed.

INTRODUCTION

The main disadvantage of the accelerating structure with spatial periodic RFQ focusing (SPRQF) (fig.1) which is based on H-cavity and realized in the linear accelerator URAL-30 [1], is the decreasing rate of the acceleration with the particle energy increase. This fact restricts the range of the applicability of these linacs. The chosen voltage distribution causes the decrease of the acceleration rate: the RF voltage across accelerating gap U_a is equal to the RF voltage across focusing (qadrupole) gap U_q for all accelerating periods (fig.2a), the RF voltage U along the H-cavity is constant. These requirements are fulfilled by a special tuning. The abandon of these requirements corrects the shown disadvantage. According to paper [2] the increase of the voltages U and U_a proportionally the relative particle velocity β, when U_q is constant, essentially extendes the range of the SPRFQF structure applicability. But, in this case, the tuning is critically complicated.

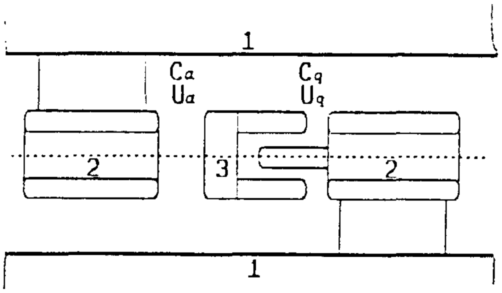

Figure 1. Accelerating period of the SPRFQF structure. 1 – parts of the 2C-cavity; 2 – electrodes; 3 – intermediate electrode.

This structure will be based on 2C-cavity [3] and used in the UNK-project. The job seeks to create the tuning method for a SPRFQF structure with increasing voltage.

The voltage U across the 2C-cavity is divided in accord with the capacitances of the accelerating C_a and focusing C_q gaps:

$$\frac{U_a}{U_q} = \frac{C_q}{C_a} \tag{1}$$

According to fig.2b, the current through the accelerating gap:

$$I_a \approx j\omega C_a \int_{S_a} \mu H_a ds \tag{2}$$

and through the focusing gap:

$$I_q \approx j\omega C_q \int_{S_q} \mu H_q ds \tag{3}$$

The current in the intermediate electrode holder is:

$$I_{int} = I_a - I_q \approx j\omega\mu(C_a \int_{S_a} H_a ds - C_q \int_{S_q} H_q ds) \tag{4}$$

The condition of the "balance", when there is no I_{int}, is

$$\frac{\int_{S_a} H_a ds}{\int_{S_q} H_q ds} = \frac{C_q}{C_a} \tag{5}$$

as follows from equations (1) and (5), the required U_a/U_q value must conform to eq.(1) and condition (5). It may be fulfilled by the tuning of the capacitances C_a, C_q and of the intermediate electrode holder angle φ (fig.2b) (changing the relationship S_a and S_q). It is clear in this case, C_q is not equal to C_a and $\varphi \neq 0$ for each accelerating period, as it was equal for the unmodified structure. According to paper [2], the increasing 2C-cavity voltage along the cavity may fulfilled by changing of the cross section area of the cavity chamber.

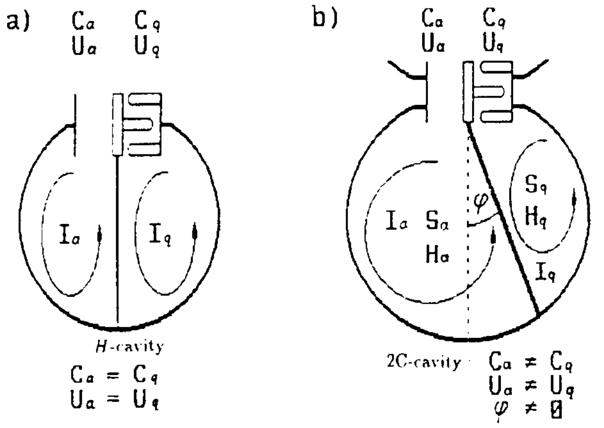

Figure 2. Cross section of H- and 2C-cavities. The electrodes are turned by 90° (for the easy-to interpretation).

To design the tuning method, the electrodes of the single accelerating period were installed in the short 2C-cavity model. The capacitance load of the model was simulated by parallel plates [4]. The voltage ratio U_q/U_a was measured by the small perturbations method [5]. According to the method

$$\frac{\Delta f_a}{f} = \frac{-k_a \int_V \varepsilon E_a^2 dv}{4W} \tag{6}$$

where Δf_a is the detuning of the unperturbed frequency f; k_a is the formfactor of the small perturbating body with values of V located in the accelerating gap; E_a is the electric field strength in the accelerating gap; W is the stored energy of the cavity.

For electrostatic approximation

$$\vec{E_a} = -U_a grad\, u = U_a \vec{F_a} \tag{7}$$

where u is the normalized potential function. There are similar equations for the focusing gap. For the relation

$$\alpha = \sqrt{\frac{\Delta f_q}{\Delta f_a}} \tag{8}$$

an equation may be obtained:

$$\alpha = \frac{U_q}{U_a} \sqrt{\frac{k_q \int_v F_q^2 dV}{k_a \int_v F_a^2 dV}} = \alpha_o \frac{U_q}{U_a}. \tag{9}$$

As follows from this equation the required relation $(U_q/U_a)_{req}$ conforms to the parameter α_{req}, which can be measured. The value of α_{req} is used for the tuning. The main problem of α_{req} determination is the α_o determination. The value of α_o is a function of the field forms in the accelerating and focusing gaps and formfactors of the perturbating body, but is not a function of the voltage. The experimental method of the α_o determination follows from equation (9):

$$\alpha_o = \alpha|_{U_q=U_a} = \sqrt{\frac{\Delta f_q}{\Delta f_a}}|_{U_q=U_a} \tag{10}$$

Therefore α_o is measured when the intermediate electrode holder is installed at the angle $\varphi = 0$. The condition of the "balance" fulfilled the increasing C_a. But, in this case, the field form in the accelerating gap is not deformed. As follows equation (9) and (10)

$$\alpha_{req} = \sqrt{\frac{\Delta f_q}{\Delta f_a}}|_{U_q=U_a} \cdot \left(\frac{U_q}{U_a}\right)_{req} \tag{11}$$

where $(U_q/U_a)_{req}$ is given before.

The knowledge of α_{req} allows one to find the angle φ_{req} corresponding to condition (5). For this, the α parameters are measured for different angles φ and function

$$\alpha = \alpha(\varphi) \tag{12}$$

is plotted. The value of the angle φ_{req}, corresponding to condition (5) and value of α_{req}, is found from this curve.

On the other hand, the angle φ may be calculated by integration of the magnetic field with respect to the corresponding areas (fig.2b) according to equations (5) and (1). This function

$$\varphi = \varphi\left(\frac{U_q}{U_a}\right) \tag{13}$$

is presented in fig.3.

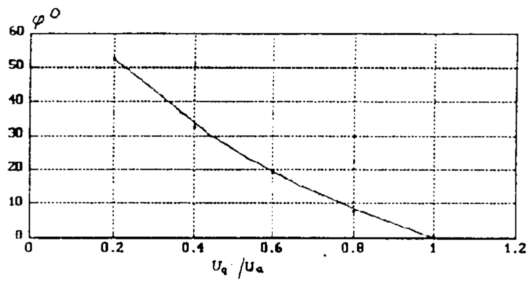

Figure 3. Angles φ of the intermediate electrod holders calculated as a function of the ratio U_q/U_a.

The comparison of the results, obtained from (12) and (13), have allowed one to make a conclusion in favour of the applicability of the suggested tuning method.

The described measurements have been carried out for seven accelerating periods of the structure with increasing voltages U_a and U. The structure had 30 periods. The measurement results are shown in table 1.

Table 1.

Parameter \ Numbers of periods	3	9	12	15	20	25	29
α_{req}	0,954	0,933	0,91	0,905	0,867	0,85	0,85
φ^o_{exp}	27,5	32,6	36,9	38,4	40,8	43,2	43,6
φ^o_{cal}	31,7	34,5	36	37,3	39,5	41,9	43,6

A long 2C-cavity model having 14 accelerating periodes have been produced for tuning the voltage partition and increase of the voltage U along the cavity. The angles φ of the intermediate electrode holders have been calculated, the values α_{req} for each period have been found from the curve, plotted according to the results of table 1.

In this case, the tuning has sought to obtain an even distribution of the focusing fields along the structure and the required value α_{req} for each period, when the currents in the intermediate electrodE holders are absent. Under such conditions, the required increase of the cavity voltage U along the cavity is achieved.

Original distributions of the values for α and focusing fields along the cavity are presented in figs.4,5. The currents were indicated in all intermediate electrode holders, but the maximum currents were in the first and last holders installed in the end cavity regions. These regions are irregular regions of the cavity. At the beginning of the tuning all holders were insulated from the cavity to exclude current effect. Under such conditions the distribution of the focusing field was tuned by decreasing the cross section areas of the chambers and by tuning the end regions. Then, the holders were connected with the cavity in turn. If the holder current appeared there, the areas S_a and S_q (fig.2b) were changed in a small range by installating special metal plates. Finally, the first and last holders were connected with the cavity, but the angles φ for these holders were found empirically. The calculation of the angles φ in the irregular regions of the cavity is doubtful.

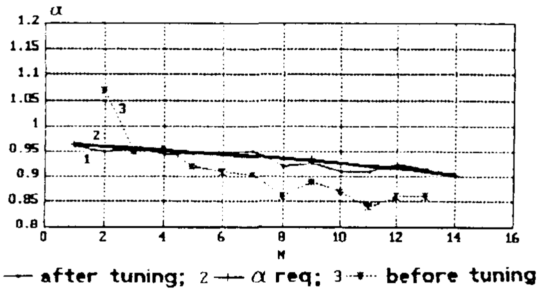

Figure 4. Distribution of the parameters α along the structure.

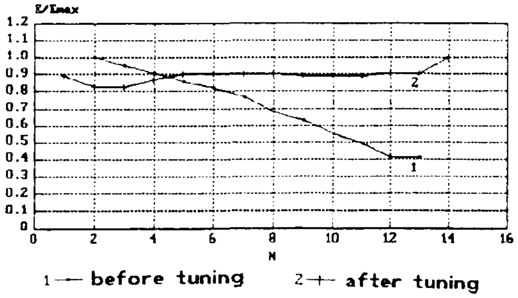

Figure 5. Distribution of the focusing fields along the structure.

The results of the tuning are presented in figs.4,5. As follows from these results, the elaborated tuning method allows one to tune the SPRFQF structure with increasing voltage.

There are some important features of the tuning:

— the currents in the intermediate electrode holders disturb the ratio U_q/U_a and field distribution, enrich the frequency spectrum of the 2C-cavity;

— poor contacts in the cavity have an effect on the amplitude oscillations, spectrum and field distribution.

CONCLUSION

The increasing voltage across the accelerating periods of the SPRFQF structure critically complicates the tuning of the structure. The tuning method of the required increasing voltage across the accelerating periods along the accelerator, ratios of the accelerating and focusing gap, voltages field distribution are offered in the paper. The accelerating structure model is tuned. Some features of the tuning are studied.

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