IHEP 2K-RFQ CAVITY STUDY

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Abstract

The abandon of a constant RF voltage on the accelerating periods of the structure with spatial periodic RFQ focusing critically extends the range of the applicability, but complicates the tuning. The tuning procedure of the required increasing voltage on the accelerating periods along the accelerator, partition of this voltage between accelerating and focusing gaps are desribed in the paper. Some features of the tuning are discussed.

1 INTRODUCTION

An accelerating complex of IHEP (Institute of High Energy Physics, Protvino) includes a linac with a final energy of 30 MeV (URAL)[1]. This is a first and up to now the only accelerator in the world on such energy with the initial and main parts built on the base of the radio-frequency quadrupoles. The complete project is developed in IHEP. The mashine comission has been made in 1977 and since 1983 it is in a full operation.

In two initial parts of the accelerator a well-known and wide used RFQ structure with modulated along cavity length electrodes is used.

The way of forming of an accelerating voltage component using the voltage on quadrupole electrodes does not allow to create the required accelerating gain. The particles during their motion along the homogenious quadrupole interact only on the certain parts with an electric RF field where the field is close to its amplitude value. Those parts of the quadrupole where the interaction with field is weak could be removed. The quadrupole channel becomes space-periodical but nearly with the same focus rigidity. The required longitudinal accelerating field component is created in the parts where the quadrupole is removed.

Based on this idea the RF field space-periodic focusing is used in the main part of an accelerator. The acceleration and focusing are accomplished in the "double gap" formed by three electrodes of a special shape (Fig. 1). One of the electrodes, "intermidiate", is under zero potential. Two others, "main", are fixed to the cuts of H-cavity. The focusing field component is created in the space between "horns", fixed on the backs of neighboring electrodes. The electrodes are installed in two chamber H-cavity (2K-Cavity) schematically shown on Fig. 2.

2 2K CAVITY TUNE

The main disadvantage of an RFQ accelerating structure on the base of H-cavity is an accelerating gain decrease,

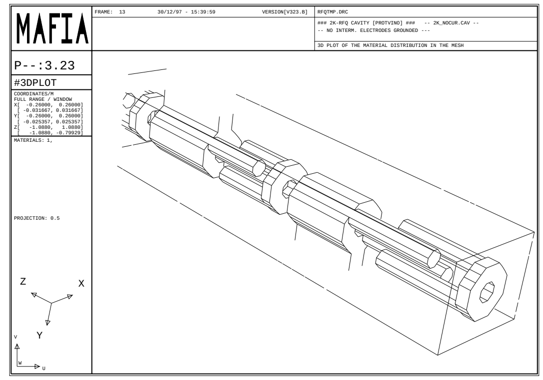

Figure 1: Electrodes at the Beginning of Cavity.

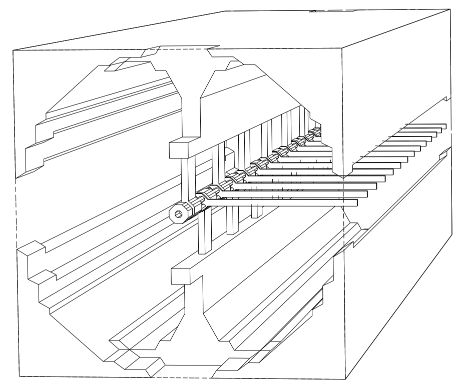

Figure 2: 2K-RFQ Cavity Geometry.

which limits an application of such structure. The reason of such decrease lies in the choosen voltage distribution on electrodes – voltages on accelerating U_{acc} and quadrupole U_{quad} gaps are equal.

During a such structure tuning a condition $U_{acc} = U_{quad}$ is accomplished by equalization of capacitances of accelerating C_{acc} and quadrupole C_{quad} gaps by means of special elements. An absence of currents along intermidiate electrodes is a moment of an equalization of gap capacitances.

This disadvantage can be eliminated by $U_{acc} = U_{quad}$ condition violation. In[2] it is shown that the accelerating voltage grow along the cavity while the quadrupole voltage kept constant reasonably increases a such structure application. For such idea realization a two-chamber (2K) cavity can be used.

A changeable voltage ratio on accelerating periods leads to a more complicate structure tuning procedure. The volatge ratio corresponds to the capacitance gap ratio –

$$\frac{U_{acc}}{U_{quad}} = \frac{C_{quad}}{C_{acc}} \qquad (1)$$

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And in the case of an abcense of a current along an intermidiate electrode –

$$\frac{\int_{S_{acc}} H_{acc} ds}{\int_{S_{quad}} H_{quad} ds} = \frac{C_{quad}}{C_{acc}} \quad (2)$$

Thus, in the considered case the task of rf tuning is to provide the required voltage ratio by means of accomplishment of a certain ratio between C_{quad} and C_{acc} at the intermidiant electrode currrent abcense. This can be achieved by a choice of intermidiant electrode ground connector position corresponding to S_{acc}/S_{quad} ratio.

3 3D CAVITY SIMULATION

To simulate this cavity structure 3D MAFIA codes have been used[3].

The main characteristics which differ an accelerating structure built on H-wave from other cavities is a small cross-section (less than λ/2) and a complicate boundary configuration. Such cavity is excited on the wave, which is similar to H-wave of a regular waveguide with the same cross-section. At the moment the most developed H-cavity is a basic cavity of a linear accelerator-injector for the Serpukhov Booster Synchrotron. An application of two-chamber 2K-cavity should result in a higher quality value than in H-cavity, a higher shunt impedance and to increase the energy range where the RFQ cavity use is more effective to compare with other accelerating structures.

During a numerical simulation the maximal number of mesh points that we used is under 1 million. The total cavity length is 2176 mm, cavity diameter is 540 mm, the electrode and apperture radius is 5 mm. The smallest mesh size is 3.3 mm. For the proper simulation of electrode structure we concentrated most of the mesh in a central region. The real electrodes should be rounded at their ends. To avoid an electrode tip radius simulation electrode lengths have been reduced by 1/3 of radius. As soon as the purpose of the work was to investigate the behaviour of a field distribution depending on intermidiate electrode positions this simplifies requirements on overall accuracy of calculations.

Fig. 3 shows the electric field distribution along cavity when all intermidiate electrodes are grounded like on Fig. 2. The inductance of the cavity walls is shunted by the inductances of intermediate electrode connectors and current flows only along few first these connectors.

To fulfill a condition (2) the connectors have been placed under a certain angles (Fig. 4). As soon as electrodes in end regions disturb a magnetic field flux the connectors close to end regions placed sligthly under different angles. The electric and magnetic field distributions for this case are presented on Fig. 5. The behaivior of an electric field distribution along cavity axes is defined mainly by the difference in the type of end region electrodes - ”horns” at the beginning of cavity and ”gap” at its end (Fig. 1). If to remove ”horns” at the beginning the electric field distribution changes into sinusoidal. Here big picks are the field in ”gaps” and two in series small picks after every big are fields between ”horns” and drift tubes.

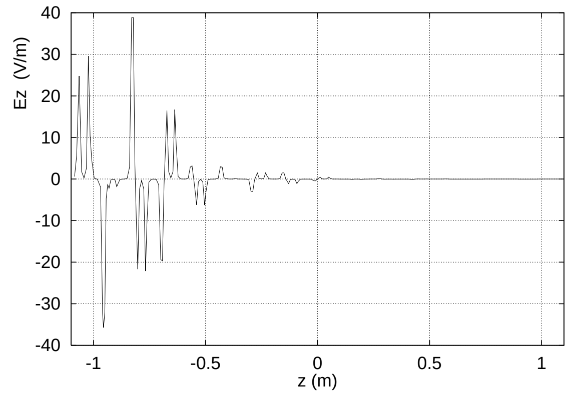

Figure 3: Electric Field Distribution for Grounded Intermidiate Electrodes at the Same Side.

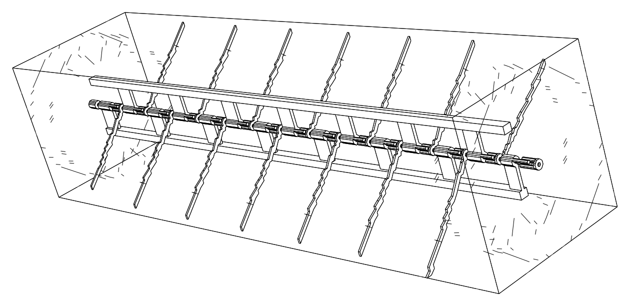

Figure 4: ”No Current” Position of Intermidiate Electrodes.

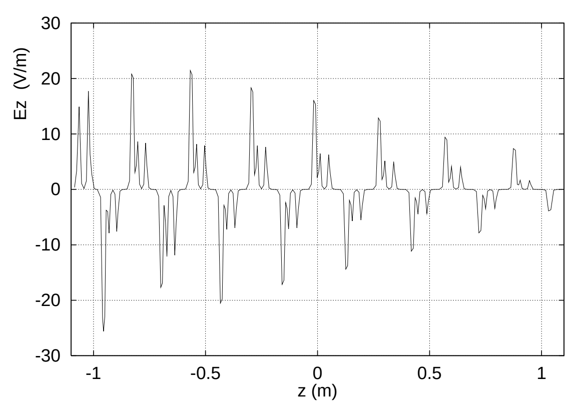

Figure 5: Electric Field Distribution for ”No Current” Position of Intermidiate Electrodes.

The required accelerating voltage grow along the cavity can be achieved by a structure cross section size change (Figs. 6- 7).

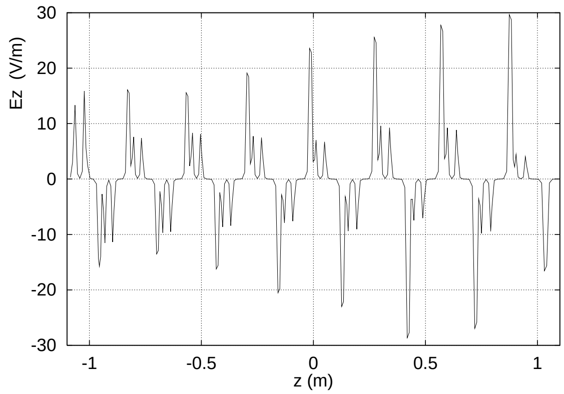

Figure 6: Electric Field Distribution Along Cone Cavity.

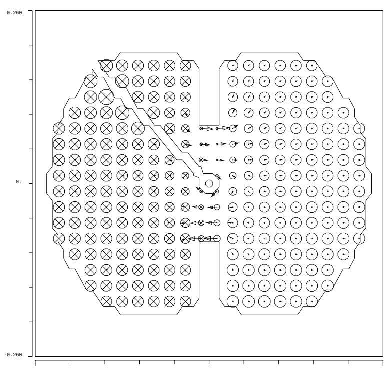

Figure 7: Magnetic Field Distribution Across Cavity.

For a fine cavity frequency tune an inductive plunger without sliding spring contacts has been proposed. The plunger design allows to work without heating of inner components of plunger housing[4]. It can be installed in end regions as well as in the middle of cavity. Fig. 8 shows the results of plunger simulations. A plunger diameter is 140 mm. In our case the plunger is installed in the minimum of the magnetic field of second harmonic.

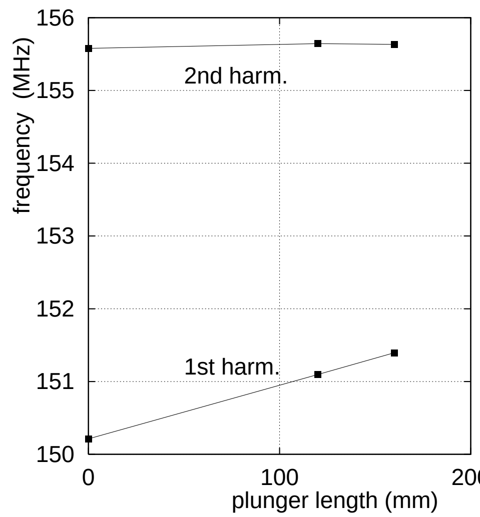

Figure 8: Cavity Frequency Dependence on Plunger Length.

4 ACKNOWLEDGMENTS

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5 REFERENCES

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