OPTIMIZATION OF IH-DTL RESONATOR FOR UNDULAC RF

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Abstract

The undulator linear accelerator (UNDULAC) was proposed earlier for ribbon ion beam acceleration [1]. UNDULAC can be realized using two non-synchronous spatial harmonics. The first one must be RF field spatial harmonic and the second one can be RF (UNDULAC-RF) or electrostatic (UNDULAC-E). The acceleration mechanism in UNDULAC is similar to inverse free electron laser (IFEL). The beam dynamics in both types of UNDULAC was studied earlier and the design of UNDULAC-E resonator was started in [1-4]. Design of the 150 MHz IH-DTL resonator for UNDULAC-RF will be presented. The optimization of longitudinal field distribution will be performed. The most effective construction will be shown. The transverse electric field distribution within drift tube will be optimized by blending of the support stems and the drift tubes.

INTRODUCTION

Nowadays the most promising way of using of the acceleration technology is creating of the high intensity low energy linear accelerators. Conventional methods of focusing by external magnetic or electrostatic lenses can not be used at low energies because the period of the RF structure is too small here. The most usable type of low energy ion beam RF linac is Radio Frequency Quadruple (RFQ). But its using is limited by the beam current value and the low rate of energy gain (usually not greater than 300–400 keV/m). Other types of RF focusing linacs are developing to increase the rate of energy gain and limit beam current.

The undulator linear accelerators with radio frequency undulator (UNDULAC-RF) [1] and with electrostatic undulator (UNDULAC-E) [2] were considered earlier. In UNDULAC the beam bunching, acceleration and focusing are realized by a combination of two non-synchronous waves (two undulators). Both UNDULAC types can be realized inside interdigital H-type (IH) resonator. Ribbon ion beams can be bunched and accelerated in UNDULAC. The IH resonator with electrostatic potential input was discussed in [4] for UNDULAC-E. The construction of the UNDULAC-RF resonator will be discussed in this paper. It should be noted that such resonator should has free especial characteristic: the slit accelerating channel is necessary for ribbon ion beam acceleration, the ratio of base and first RF field special harmonics amplitude should be equal to 0.25-0.3 for effective beam focusing and the field amplitude should increase in front end of structure to realize the beam bunching [1].

Two schemes of IH resonator can be used for low energy high intensity ribbon beam acceleration in UNDULAC-RF. Drift tubes can be placed horizontally or vertically relatively to resonator vanes (see Fig. 1 and Fig. 6 respectively). The operating frequency is 150 MHz at π mode. These two schemes will be compared by the electrodynamic efficiency: *Q*-factor and shunt impedance R_{sh} and transverse electric field distribution within the drift tube.

HORIZONTALLY PLACED TUBES

The computer simulation of RF field distribution in interdigital H-type resonator for low energy high intensity ribbon beam acceleration with horizontally placed drift tubes was performed and electrodynamic characteristics of the structure were calculated. *Q*-factor is 6100 and shunt impedance is 47 MOhm/m.

Further optimization of electric field longitudinal distribution was done by cutting of supporting vanes. The magnetic field is pressed out due to vanes cutting. Therefore RF power transfers from magnetic to electric field and electric field aligns at the front end of the resonator. A number of different variants of wanes cutting were analyzed. The top view of the most effective variant if the structure is shown in Figure 2.

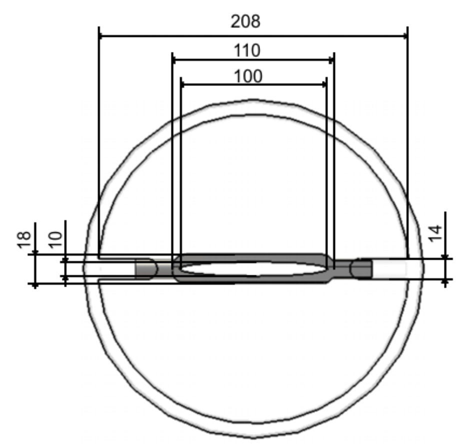


Figure 1: IH resonator with horizontally placed drift tubes. Front view.

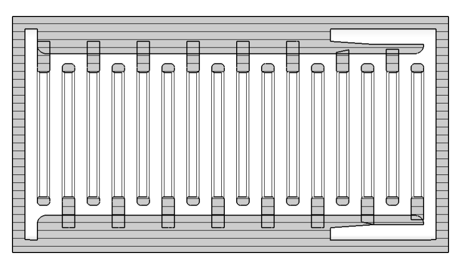
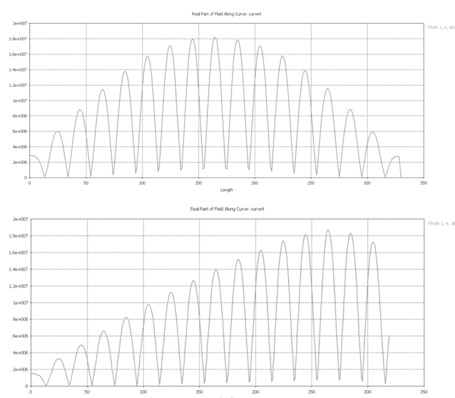


Figure 2: IH resonator with horizontally placed drift tubes and vanes cutting. Top view.

The resonant frequency decreases due to the vanes cutting and the resonator diameter should be reduced from 208 mm to 185 mm for tuning.

The longitudinal field component on the axis of accelerating-focusing structure is shown in Figure 3 for rectangle (a) and cut off (b) vanes. The Q-factor is 4500 and shunt impedance 28 MOhm/m for the structure with cut off vanes.

The initial tuning of RF field distribution was done, however such electrodes are unuseful because they have low mechanical strength. Therefore the design of electrodes should be modified.



a

b

Figure 3: Distribution of E-field on longitudinal axis in resonator with horizontally placed drift tubes (a) – without optimization, (b) – with cutted planes.

Electrodes were thickened to increase the mechanical strength (see Fig.4). The computer simulation of the structure with thickened electrodes was done. The resonant frequency reduces due to increasing of the capacitance between electrodes and the resonator diameter was decreased again to 170 mm for resonator tuning to 150 MHz.

Electrodynamic characteristics of the structure with vanes cutouts and thickened electrodes were calculated: Q=4100 and R_{sh}=20 MOhm/m.

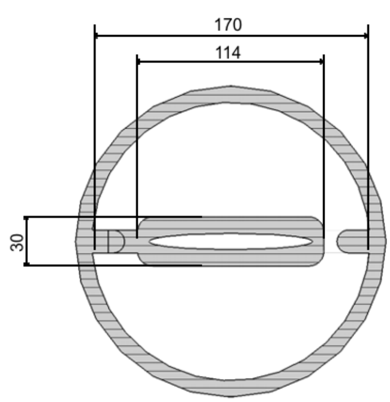
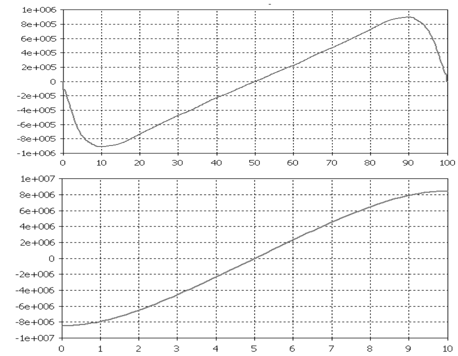


Figure 4: Horizontally placed drift tubes into IH-resonator with thickened electrodes.

The transverse electric field distribution within drift tube is shown in Figure 5. Results obtained by simulation agree to theoretically predict. The transverse component near the electrode is corrupted. However, it does not matter to the process of ion beam acceleration due to the beam is accelerated near the channel axe.



a

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Figure 5: Resonator with horizontally placed tubes distributions: electric field within drift tubes (a) – horizontal axis, (b) – vertical axis.

VERTICALLY PLACED TUBES

IH-resonator with vertically placed drift tubes was studied. The computer simulation of RF field distribution was done initially, and electrodynamic characteristic were calculated. Q-factor is 5100 and shunt impedance is 43 MOhm/m, this case that is lower comparatively the same characteristics of IH-resonator with horizontally placed drift tubes. Q-factor and shunt impedance are reduced because the vertically placed drift tubes give more distortion of the magnetic field than horizontally placed tubes (see Fig. 7).

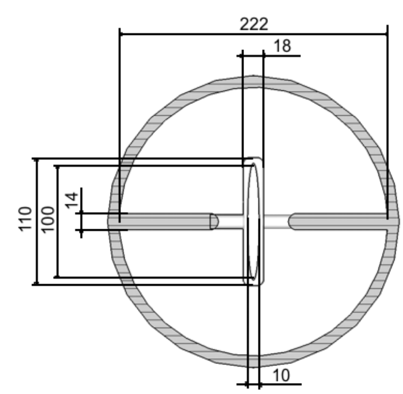


Figure 6: IH-resonator with vertically placed drift tubes.

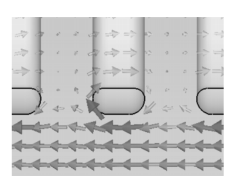


Figure 7: Distortion of magnetic field around vertically placed drift tubes.

The optimization of longitudinal field distribution was done similarly to previous chapter by cutting of the supporting vanes. The top view of the most effective structure variant is shown in Figure 8. The tank diameter was reduced from 222 mm to 196 mm to tune the resonator to 150 MHz. Q-factor and shunt impedance for structure with vanes cutouts are Q=4900 and R_{sh}=38 MOhm/m. The field distribution along of the accelerating-focusing structure was calculated (see. Fig. 9).

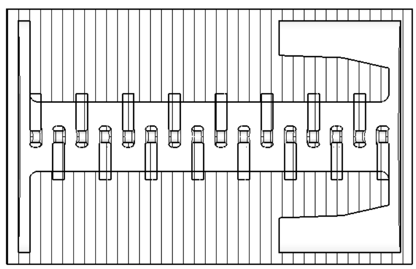
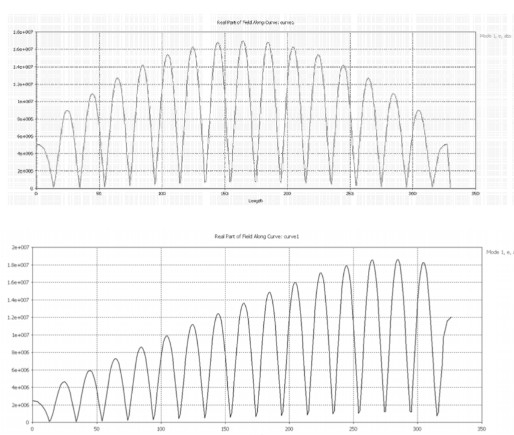


Figure 8: IH-resonator with vertically placed drift tubes and vanes cutouts. Top view.



a

b

Figure 9: Distribution of E-field along of the longitudinal axe (a) –without optimization, (b) – with cutted planes

Electrodes were thickened to increase the mechanical strength as it was done for resonator with horizontally placed drift tubes early (see Fig.10). The tank diameter was reduced to 156 mm to tune the resonant frequency. Electrodynamic characteristics of the structure with vanes cutouts and thickened electrodes were calculated: Q=4100 and R_{sh}=20 MOhm/m.
Transverse electric field distributions within drift tube were calculated (see Fig. 11). Distributions are similar to the results obtained for resonator with horizontally placed drift tubes.

CONCLUSION

A number of IH resonator schemes for low energy high intensity ribbon ion beam acceleration were discussed. The optimal accelerating structures without optimization of the longitudinal electric field distribution and with real design of electrodes and optimization of longitudinal electric field distribution were designed. Resonators with horizontally and vertically placed drift tubes were discussed. The first scheme has higher Q-factor and shunt impedance but both types can be used. The mechanical and thermal characteristics of electrodes will define the possibility of using.

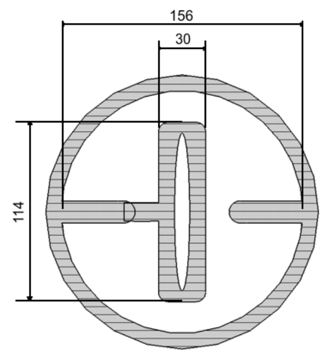
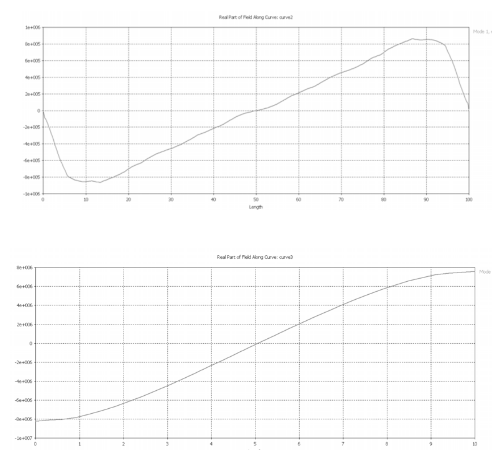


Figure 10: IH-resonator with vertically placed drift tubes and thickened electrodes.



a

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Figure 11: Resonator with vertically placed tubes distributions: electric field within drift tubes (a) – vertical axe, (b) – horizontal axis.

REFERENCES

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