THE NEW RF-DESIGN OF THE 36 MHz-HSI-RFQ AT GSI

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Abstract

In Darmstadt/Germany the existing accelerator cite GSI is expanding to one of the biggest joint research projects worldwide: FAIR, a new antiproton and ion research facility with so far unmatched intensities and quality. The existing accelerators will be used as pre-accelerators and therefor need to be upgraded to fulfill the requirements with respect for intensity and beam quality. In a first step the 9.2 m long 36 MHz-HSI-RFQ for high current beams will get new electrodes to reach the specific frequency, to allow a higher electric strength and to avoid unwanted multipole components. Therefor several simulations with CST MWS have been done. The parameters and results of the rf-design will be presented.

INTRODUCTION

The existing HSI-RFQ is part of the linear accelerator UNILAC at GSI which has a length of 120 m and consists of the RFQ (up to 120 keV/u), two IH-DTL (up to 1.395 MeV/u), four Alvarez cavities (up to 11.4 MeV/u) and 15 shiftable single gap resonators [1].

The facility is expanding with the FAIR project to one of the biggest joint research projects worldwide. With the physics at FAIR questions of the evolution of the universe, the structure of matter and its constituent parts will be approached [1]. Therefor the existing cite should be used as pre-injector. To fulfill the requirements (i.e. a huge range of beam intensities and energies, highest beam quality) a lot of modifications and updates are needed [2].

The RFQ was built in 1996 and modified in the past years. With the actual structure the emittance is too high for the following IH-DTL which leads to unwanted beam losses and a low brilliance. The planned upgrade of the electrodes should result in an increase of the brilliance.

The RFQ is designed as an IH structure and consists of ten 92.5 cm long modules, the last two of them are shown in Fig. 1. One can see the big undercut at the very end, which is already part of the existing accelerator and which can be found at the beginning of the first module, too. Each pair of electrodes is mounted on one carrier ring to be held by the stem. Because the main structure should not be changed for practical, time and financial reasons, only the electrode design and the carrier rings for the electrodes are part of this study.

For the simulations a model of each module was created with its special parameters and simulated separately. The average aperture and average electrode tip radius for each module were taken from the new beam dynamics [3] and are shown in Table 1.

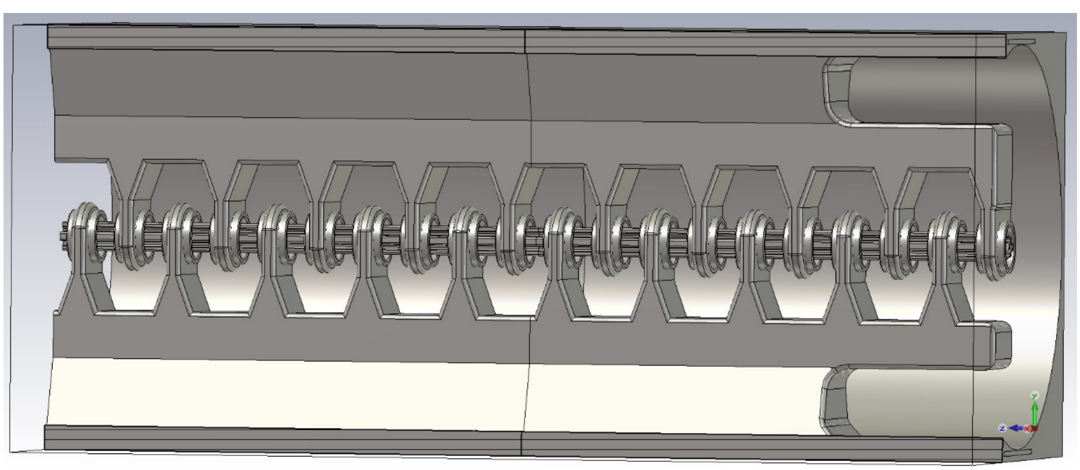

Figure 1: Modules #9 and #10 with large undercut at the end.

Table 1: Average Aperture and Tip Radius Values from the New Beam Dynamics

	module 1	*module 2 & 5*	*module 3*	*module 4*	*module 6 to 9*	*module 10*
mean aperture *a* [mm]	**7.2**	**5.6**	**5.3**	**5.4**	**5.7**	**5.7**
mean tip radius R_0 [mm]	**4.9**	**3.9**	**3.7**	**3.8**	**4.0**	**4.0**

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Table 2: Optimized Parameters and Observed Values

	module 1	*module 2 & 5*	*module 3*	*module 4*	*module 6 to 9*	*module 10*
ring nose [mm]	**15**	**14**	**13**	**14**	**15**	**13**
shoulder height [mm]	**12**	**9**	**9**	**9**	**9**	**9**
shoulder angle [deg]	**45**	**45**	**45**	**45**	**45**	**45**
frequency [MHz]	**36.06**	**36.05**	**36.02**	**35.98**	**36.01**	**36.03**
Q-value	**11676**	**15736**	**15772**	**15717**	**15786**	**11664**
R_P-value [kΩm]	**636**	**914**	**904**	**906**	**935**	**687**
E_{peak} [MV/m]	**31**	**25**	**27**	**26**	**24**	**33**

PARAMETER SWEEPS

With this models several parameter sweeps were performed to reach the right frequency. Therefor the following parameters have been varied (Fig. 2):

- the height of the electrode shoulder *h*
- the angle of the electrode shoulder *α*
- the length of the carrier ring nose *L*.

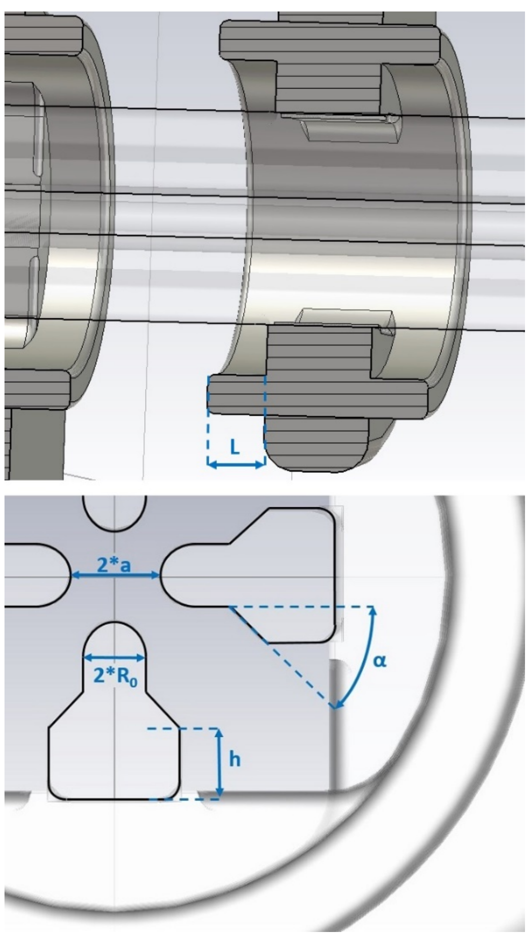

Figure 2: Parameters for sweep: on top the carrier rings, at the bottom the electrodes in beam direction.

In Table 2 frequency optimized parameters and observed values are shown.

RADIAL E-FIELD

The transverse radial E-field was studied to check the multipole components in the beam area between the electrodes. Therefor three circular curves were set around the beam axis (see blue circles in Fig. 3). In Fig 4 this E-field component is presented for the inner curve, it shows a very good quadrupole behaviour. The maximum value for the different parameter sweeps differs only by 2.5 %. For the other two curves it looks quite similar while the ratio of the maximum value between the three curves is 1:2:3 (from inside to outside).

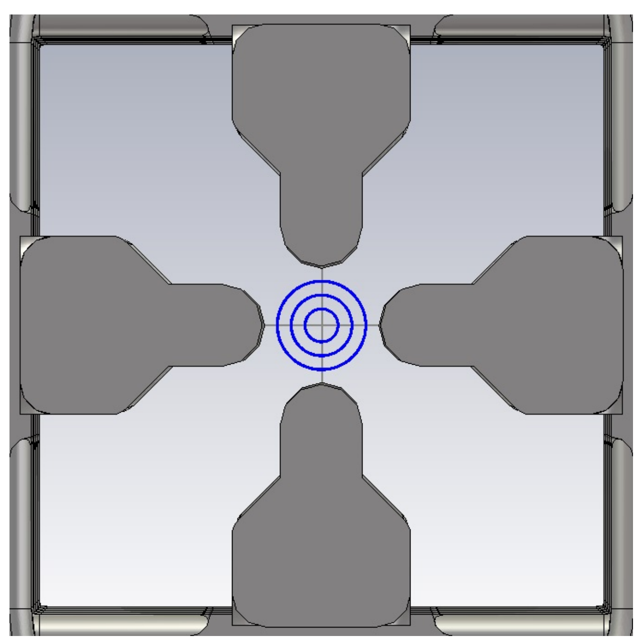

Figure 3: Curves between electrodes.

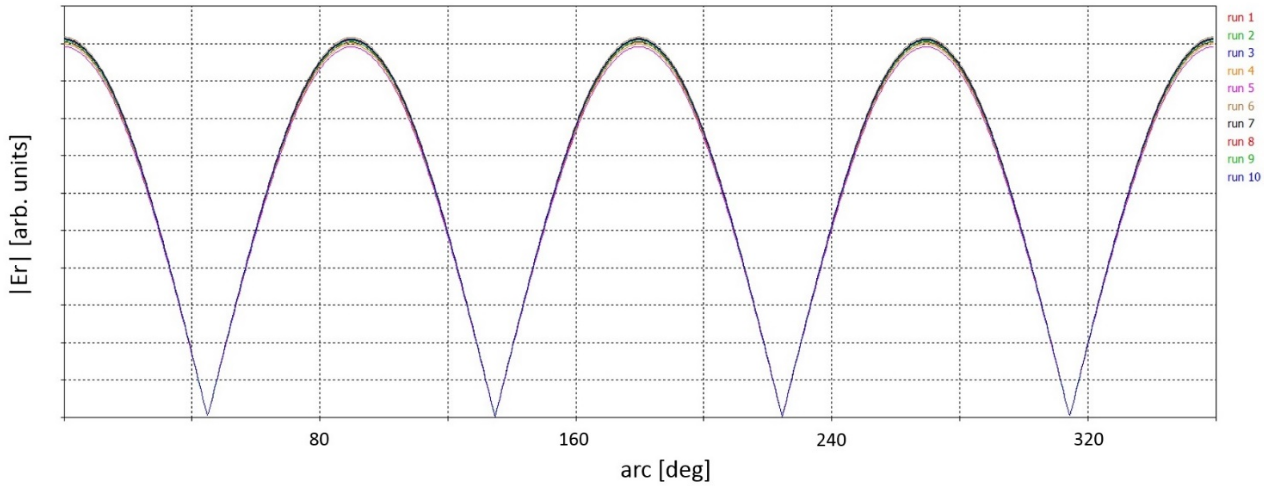

Figure 4: Radial E-field component between the electrodes for different parameter sweeps.

CONCLUSION

With respect for the given accelerator structure and the new beam dynamics [3] the aim for this work was to create a new electrode design and new electrode carrier rings to fulfill the new requirements. First results are presented.

For the modules #2 to #9 very good results for Q-value, R_P-value and peak value of the E-field with the desired frequency where reached. Also the radial E-field component between the electrodes shows the desired quadrupole behaviour.

But the first and last modules have a much lower Q-value and R_P-value as well as a much higher peak value for the E-field. Furthermore the electrode shoulder in the first module needs to be much higher to get the right frequency. For manufacturing reasons, a constant shoulder height and angle are preferred.

It was figured out that the undercut at the existing accelerator is already filled partly by displacing material. So next step will be to check these modules with smaller undercuts to maybe get better results.

Afterwards the new design considering the new beam dynamics will be finished and ready for manufacturing.

REFERENCES

[1] GSI, *https://www.gsi.de*

[2] L. Groening *et al.*, "Upgrade of the GSI Universal Linear Accelerator UNILAC for FAIR", presented at IPAC'16, Busan, Korea, May 2016, paper MOPOY017, this conference.

[3] C. Zhang *et al.*, "HSI RFQ Upgrade for the UNILAC Injection to FAIR", presented at IPAC'16, Busan, Korea, May 2016, paper MOPOY016, this conference.

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