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LINAC 2016, 28TH LINEAR ACCELERATOR CONFERENCE, EAST LANSING, MI USA, SEPTEMBER 25 - 30, 2016

Advanced Design Optimizations of a Prototype for a Newly Revised 4-Rod CW RFQ for the HLI at GSI

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Abstract:

Within the scope of the FAIR project (Facility for Antiproton and Ion Research) at GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany, the front end of the existing High Charge State Injector (HLI) is upgraded for cw operation. The dedicated new 4-Rod RFQ structure is currently being designed at the Institute for Applied Physics (IAP) of the Goethe University of Frankfurt. The overall design is based on the RFQ structures that were originally developed for FRANZ and MYRRHA. Regarding the HLI-RFQ the comparatively low operating frequency of 108 MHz causes a general susceptibility towards mechanical vibrations especially concerning the electrodes because of the necessarily larger distance between the stems. Besides RF simulations and basic thermal simulations with CST Studio Suite, the key issues like mechanical electrode oscillations as well as temperature distribution from heat loss in cw operation are investigated with simulations using ANSYS Workbench. At first instance a dedicated 6-stem prototype is currently being manufactured in order to validate the simulated RF performance, thermal behavior and structural mechanical characteristics.

Mechanical Electrode Eigenmodes

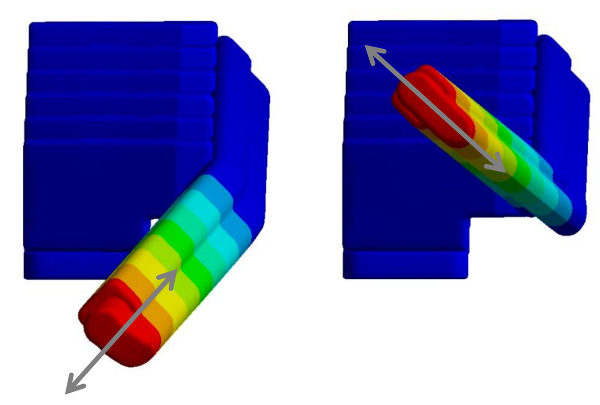

Fig. 1: Tangential (*left*) and radial (*right*) eigenmodes of the electrode extension

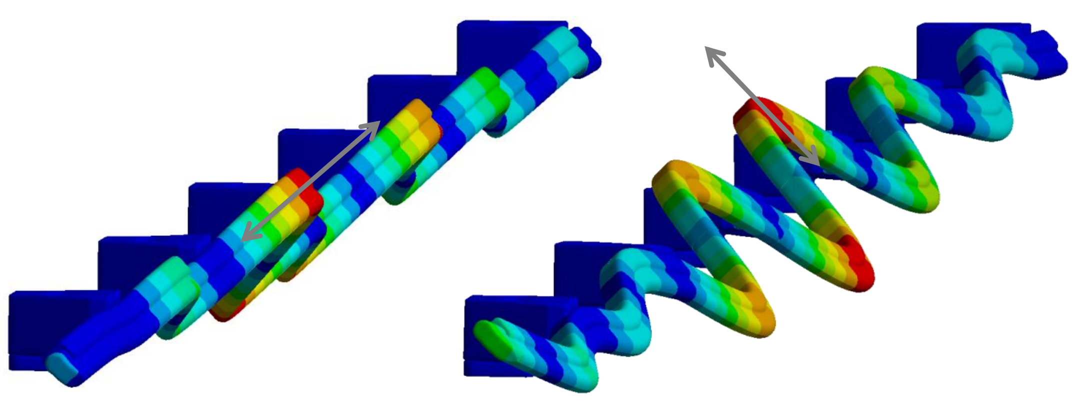

Fig. 2: Tangential (*left*) and radial (*right*) eigenmodes of the entire electrode rod

- the existing HLI-RFQ suffers from radial mechanical vibrations of the electrodes, causing strong modulated RF power reflections with a frequency of 500 Hz
- tangential electrode vibrations were identified at approximately 350 Hz

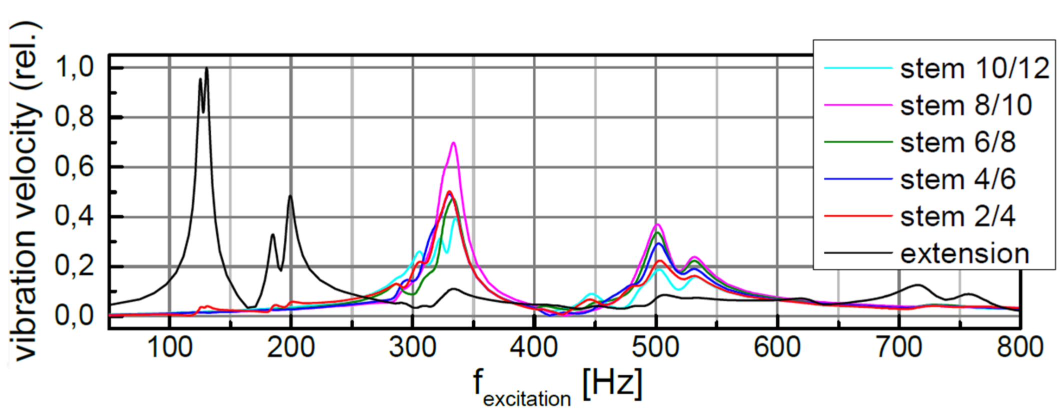

Fig. 3: Simulated resonance response spectrum

RF- and Structural Mechanical Design Optimizations

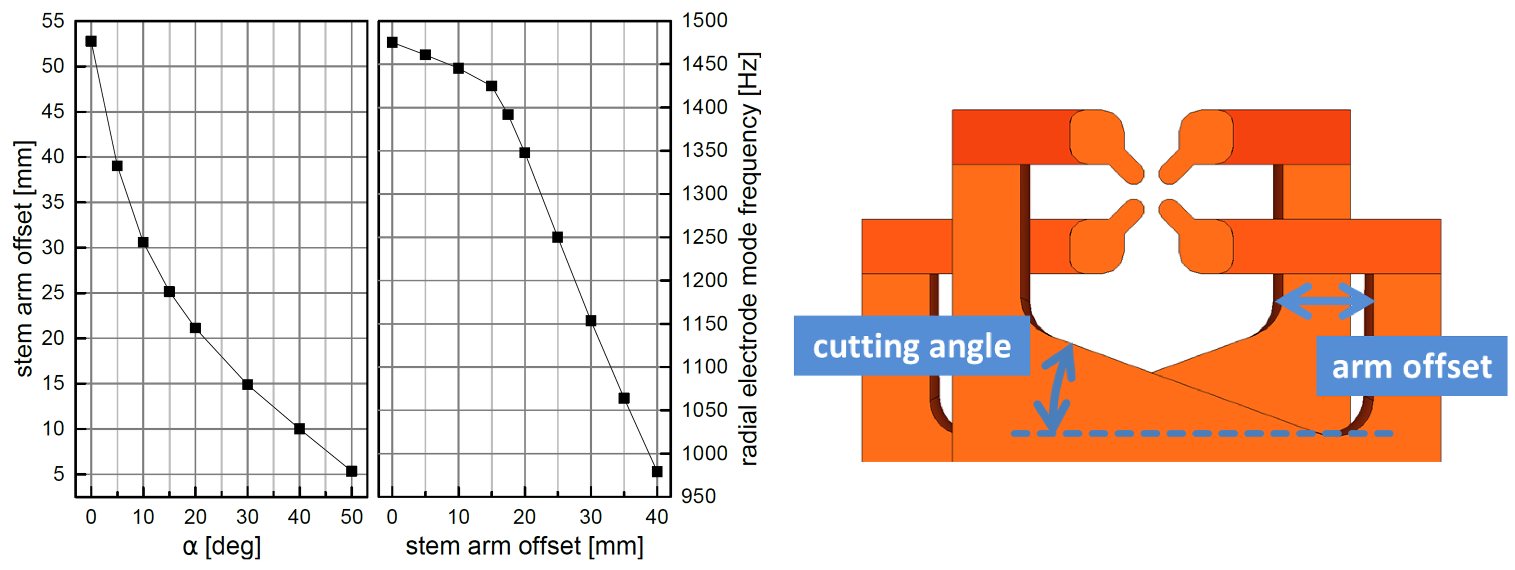

Fig. 4: Required stem arm offset for full dipole compensation as function of the stem cutting angle and effect on the radial electrode mode frequency

- the electric dipole component could be compensated entirely by applying a stem cutting angle of 30° and a stem arm offset of 15,9 mm
- overall the resonance frequencies of the RF affecting mechanical electrode modes could be increased by a factor of approximately 4 compared to the existing HLI-RFQ

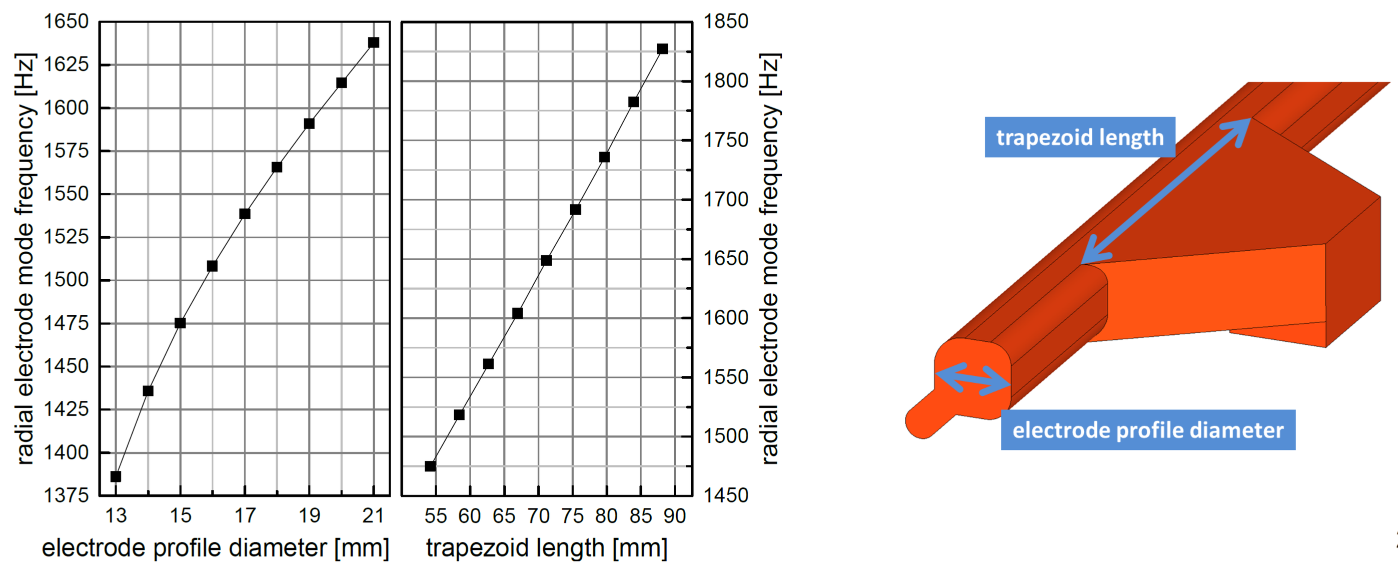

Fig. 5: Radial electrode mode frequency as function of the electrode profile diameter and base length of the trapezoidal mounting

- while thicker electrodes result in a higher capacity, thus significantly impairing shunt impedance, the geometry of the electrode mountings has a negligible capacitive influence
- implementing large trapezoid lengths is structural mechanically highly beneficial
- the finally applied electrode diameter is 17 mm and the trapezoid base length is 89,2 mm

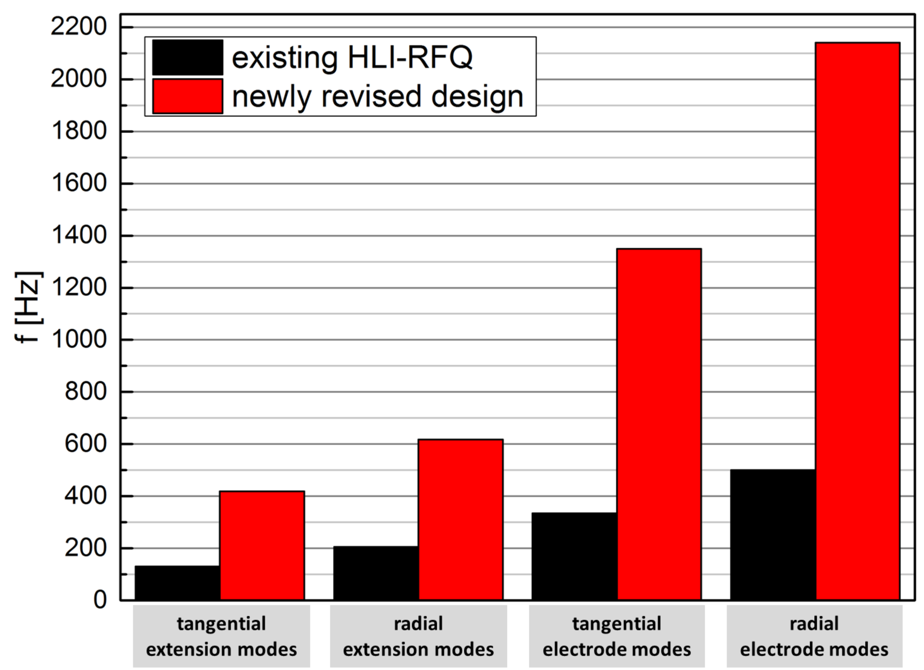

Fig. 6: Mechanical electrode resonance frequencies of the existing HLI-RFQ and the newly revised design

Final Prototype Design

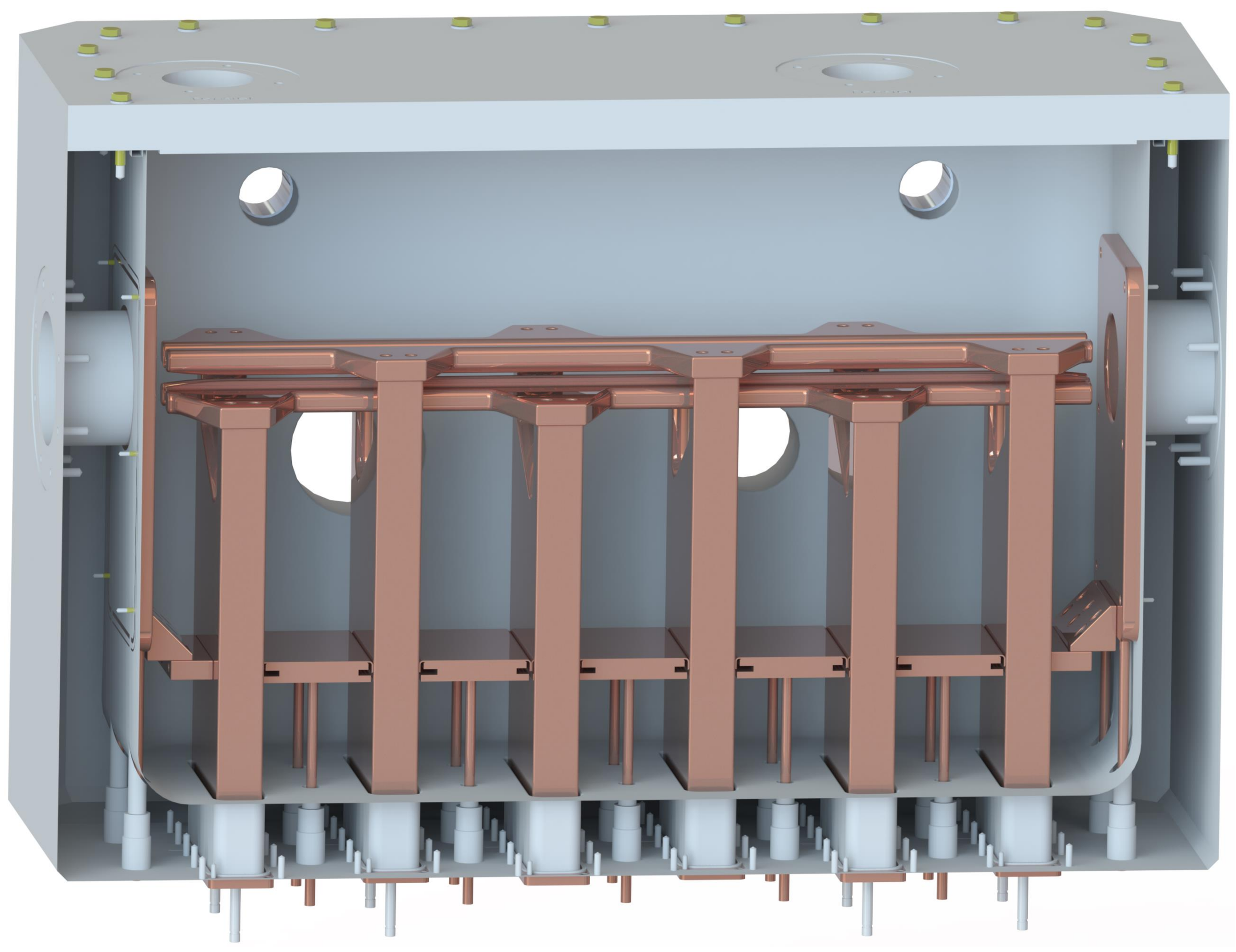

Fig. 7: Final 6-stem prototype design

- the 6-stem configuration reproduces a mechanical resonance mode spectrum that is comparable to a longer structure
- the RFQ tank is fitted with 4 windows for vibrometer measurements of electrode vibrations, targeting two designated points from two spatial directions
- each stem is fitted with a drilled channel for temperature sensors

RF frequency [MHz]	108
shunt impedance [kΩ·m]	115
electric dipole ratio [%]	≈ 0
power loss [kW/m]	31,3
reference electrode voltage [kV]	60
tuning range (tuning plates) [MHz]	± 15
dynamic tuning range (plunger tuner) [kHz]	± 200
electrode length [mm]	702
aperture radius [mm]	4
electrode radius [mm]	3
stem distance [mm]	120
stem height [mm]	282,7

Tab. 1: Simulated RF properties and design parameters

- the stated value for the shunt impedance is scaled down with a factor of 0,75 from the CST MWS simulation result
- the final full-size HLI-RFQ with an electrode length of approximately 2 m and an expected power dissipation of 31,3 kW/m at a reference electrode voltage of 60 kV can be operated with a 100 kW power amplifier