Development and Measurements of a 325 MHz Ladder-RFQ

Max Schütt[1], Ulrich Ratzinger[1], M. Obermayer[1], A. Schnase[2]

[1]) Institut für Angewandte Physik, Goethe-Universität, Frankfurt am Main, Germany
[2]) GSI, Darmstadt, Germany

Motivation & Parameters

For the research program with cooled antiprotons at FAIR a dedicated 70 MeV, 70 mA proton injector is required. The first rf accelerator element is a 325 MHz RFQ accelerating from 95 keV to 3.0 MeV.

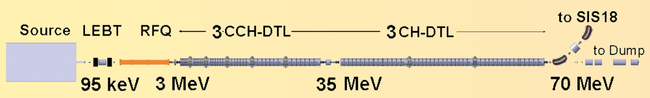


Fig. 1: Overview of the FAIR Proton-Linac.

RFQs beyond 300 MHz were realized in 4-Vane-type geometry so far. IAP has a tradition in developing 4-Rod-type RFQs for many years. This RFQ-type is dominating at lower frequencies. A first attempt towards a high frequency 4-Rod-type RFQ was made in a model study at LANL [1]. Very promising results have been reached with a ladder type-RFQ, which has been investigated since 2013. In order to verify the capabilities, a prototyp has been designed, commissioned, manufactured and measured.

Tab. 1: Important parameters and requirements of the prototype RFQ. *) simulated, **) measured

Parameter	Value	Parameter	Value
Frequency	325.224 MHz	No. Of Cells	10
Q-Value	7200* / 4700**	Ladder Height	285 mm
Loss (calc.) peak/av.	160 kW / 130 W	Ladder Width b	150 mm
Shunt Impedance	42* / 29** kΩm	Ladder Thickness	20 mm
Voltage	80 kV	Ladder Distance	40 mm
Beam Current	<100 mA	Mini-Vane Length	630 mm

Prototype

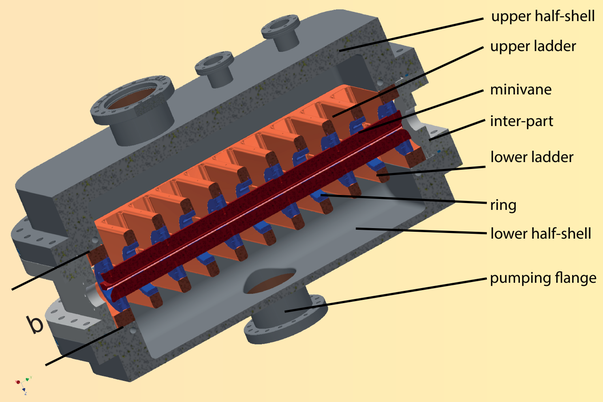
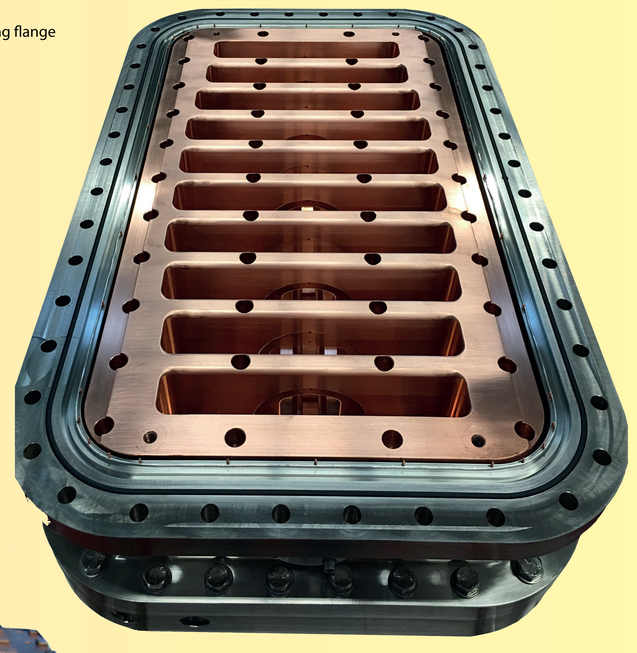


Fig. 3: RFQ with an open tank during assembly. The ladder-RFQ is a line-type resonator and therefore mostly insensitive to variations of the tank size. The rf is defined by the dimensions of the ladder.

Fig. 2: Isometric view of the prototype RFQ. It consists of 10 cells (periodic length 60 mm). The ladderstructure is embedded in a steel tank.



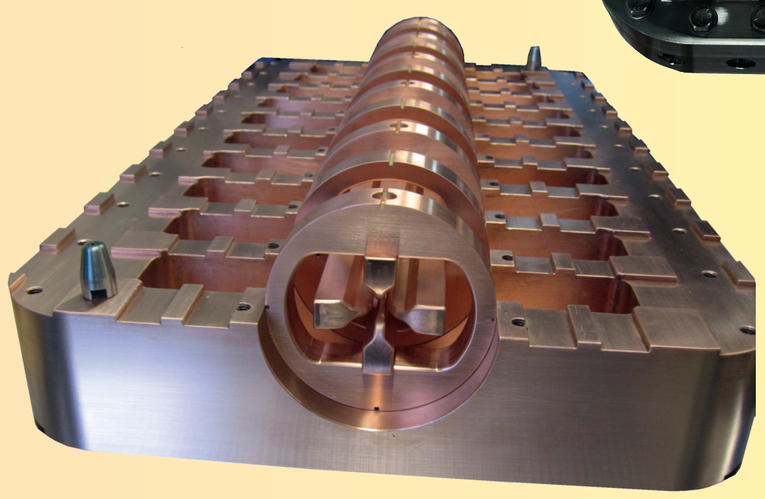


Fig. 4: Ring-electrode system after manufacturing. The rings provide the mechanical solidity and alignment of the rods as well as the best possible rf-contact.

Measurements, Tuning & RF

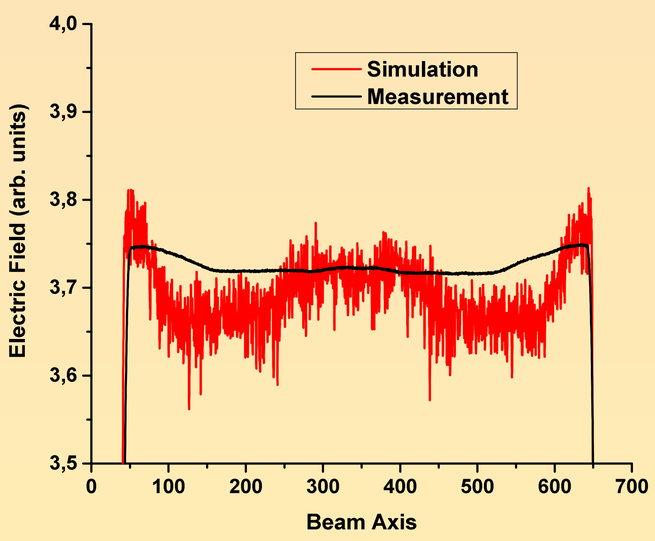


Fig. 5: Measurement of the electric field flatness. The RFQ was tuned by adjusting the hight of each cell. The hights of the cells of the ladder were determined by minimizing the relative differences of the electric field on the beam axis in the simulation. After a cnc machining the overall flattness decreased to 0,4% and below 0,1‰ on the 70% of the beam axis. The flatness is not effected by the frequency plungers.

Fig. 6: Visualisation of the Bead Pull Measurement. The Bead Pull was made of a teflon cylinder with a length of 10 mm. The radius of 3.42 mm was adjusted to the aperture, which results in a perfect conducting and an increased influence to the phase shift. The electrodes of the prototype are unmoldated.

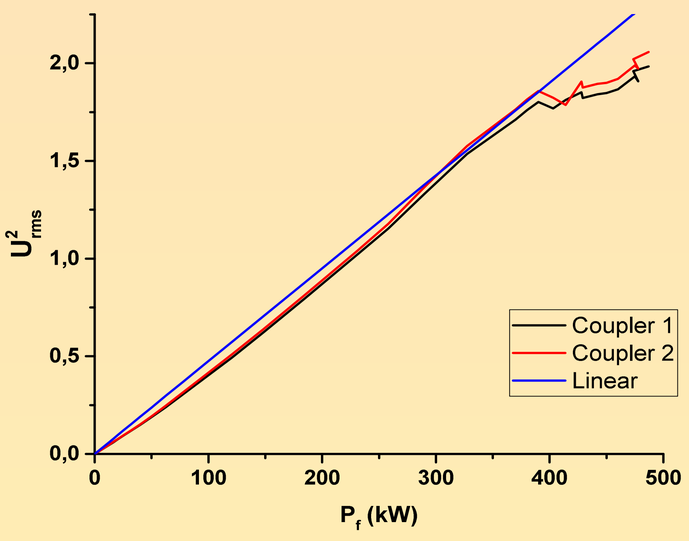


Fig. 7: Stored energy in the RFQ in dependence of the forward power P_f coupled into the RFQ. The linearity holds up to 400 kW before field emission on the surface and dark currents become relevant. The kilpatrick value reached values up to 2.8.

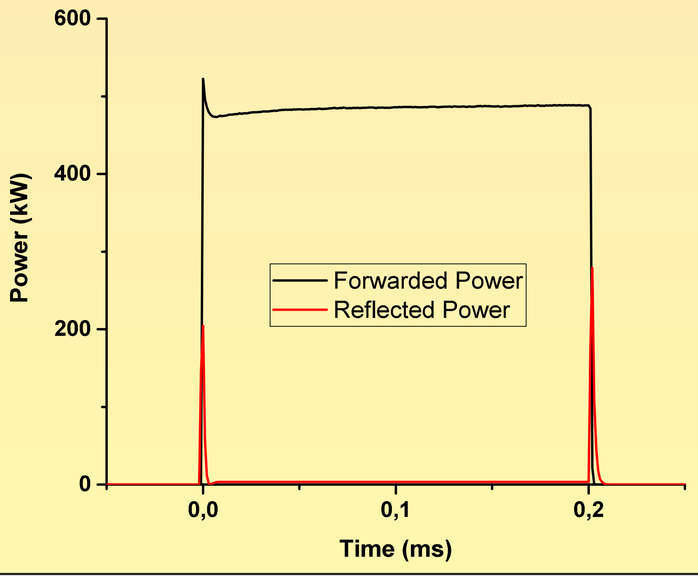


Fig. 8: A power measurement up to 487 kW was done at the GSI test stand at the end of Mai 2016. Multipacting steps could be conditioned within one day. The high power conditioning took place during 9 days.

Sources: [1] M.J. Browman, G. Spalek, P.B. Friedrichs and T.C. Barts, “Studies of the Four-Rod RFQ Using the MAFIA Codes”, Proceedings of LINAC88, Newport, Virginia, p. 119.
[2] U. Ratzinger, K. Kaspar, E. Malwitz, S. Minaev, R. Tiede, “The GSI 36 MHz High-Current IH-Type RFQ and HIIF-relevant Extensions”, Nucl. Instr. and Meth. A 415 (1998), p. 281-286.

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further information: schuett@iap.uni-frankfurt.de