

# THE MAFF IH-RFQ TEST STAND AT THE IAP FRANKFURT\*

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## Abstract

The IH-type RFQ for the MAFF project at the LMU in Munich is presently under construction and will be integrated into a beam test stand at the IAP in Frankfurt. It is the second IH-RFQ after the HIS at GSI [1] and the first one that can be directly compared to a very similar 4-rod type [2] machine, namely the REX-ISOLDE RFQ at CERN. The MAFF RFQ has been designed to accelerate rare isotope beams (RIBs) with mass to charge ratios  $A/q$  up to 6.3 from 3 keV/u to 300 keV/u at an operating frequency of 101.28 MHz with an electrode voltage of 60 kV. First RF-measurements have already been executed and can be compared to appropriate simulation results. Parts of the test stand are currently under construction, such as the volume ion source for  $He^+$  at an extraction voltage of 12 keV and an electrostatic quadruplet for injection with an integrated steering system. These tests and accompanying theoretical investigations will be done with special respect to the applicability of such normal conducting RFQ accelerators to the EURISOL post accelerator [3].

## INTRODUCTION

The MAFF-IH RFQ [4] parts have been manufactured at the NTG, the final acceptance has been in May 2005. The assembling of the parts took place in Frankfurt at the IAP (Fig. 1). The structure is generally divided into 7 separate modules. Each of them has been equipped with electrodes first and assembled on the test bench later on. During installation we have executed accompanying rf-measurements to prove the reliability of earlier simulation results that have been done with CTS Microwave Studio (MWS) and MAFIA. The deviations from the theoretically expected design values were in some cases slightly larger than expected. We are now trying to determine how these simulations have to be prepared to get most reliable results for our application.

In parallel we have built a filament driven volume ion source [5] to provide a 12 keV  $He^+$  beam for testing the RFQ. After assembling the source it has been measured with our slit grid emittance measuring system and a faraday cup to estimate the beam current.

The beam will be matched to the acceptance of the RFQ by means of an electrostatic quadrupole quartet with

additional steering elements [6], which is currently mounted to the test bench.



Figure 1: The MAFF IH-RFQ.

## LOW LEVEL RF-MEASUREMENTS

One of the main aspects with the IH-type structure is an expected low power consumption resp. a high quality factor  $Q$  and also a comparatively high shunt impedance ( $R_p$ -value). To give an idea of what the power consumption of the IH-RFQ in total will be, we have done some preliminary RF-measurements on a single module (No. 6) and compared them to appropriate MWS simulations, which have been done for both, the single module and the whole thing. Meanwhile we have assembled and measured the total structure and the results do fit quite well to the prognosis as shown in table 1.

Table 1: Low level RF-measurements.

	Module (No. 6)		IH-RFQ in total		
	Simulation	Measurement	Simulation	Prognosis	Measurement
Frequency [MHz]	127.035	129.882	98.747	100.96	104.702
Quality Factor $Q$	4790	3275	7869	5380	5750
$R_p$ -value [k $\Omega$ ]	303	153	91	53	56
Power Consumption at 70 kV [kW]	-	-	-	92	88

However the resonance frequency is with 104.7 MHz about 3.4% above the design value of 101.28 MHz, which can be tuned by the scheduled tuning plungers, but

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is considered to be rather high compared to simulation results. We found out that there is a dependence on the grid resolution and the way the structure is discretized, new calculations ended up with 103.5 MHz. Measurements on a simplified RF-model and comparison to appropriate calculation results are currently under investigation for optimization. On the basis of these low level measurements the shunt impedance of the IH-RFQ is with 168 k $\Omega$ m about 15% greater than the one of the 4-rod type REX-ISOLDE RFQ with 147 k $\Omega$ m.

The voltage distribution along the electrodes has been measured by means of a perturbing capacitor of 1.5 pF, which had been mounted between the electrodes at different longitudinal positions. Since the aperture changes from 3.7 to 4.5 mm right in the middle of the structure the capacity decreases consequently, causing a so called unflatness of about  $\pm 5\%$ , which is decreasing from the beginning to the end linearly. This can be equalized and even a little overcompensated again by means of the tuning plungers as illustrated in Fig. 2 and 3.

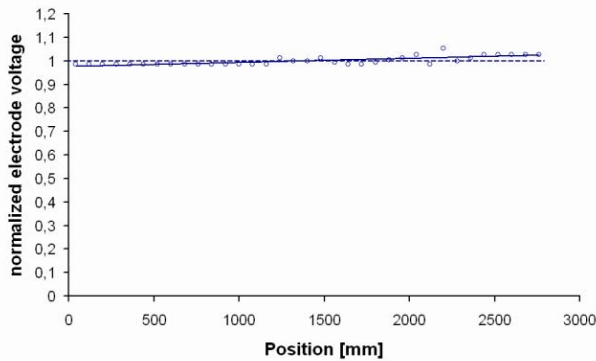


Figure 2: Flatness of the IH-RFQ.

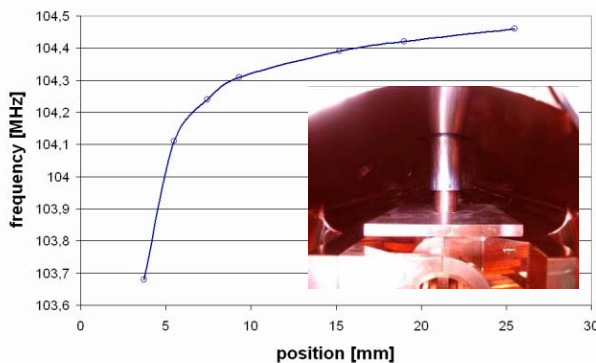


Figure 3: Tuning range of a tuning plunger (picture). Four of these devices are scheduled.

### THE VOLUME ION SOURCE

A dedicated volume ion source (Fig. 4) has been built at the IAP and already been set into operation on our slit grid emittance measuring system. The estimated beam current is about 0.5 mA. The measured normalized rms emittance is  $\epsilon_{\text{rms},n} = 0.022 \pi \text{ mm mrad}$  (Fig. 5). These parameters are well suited for our planned experiments.

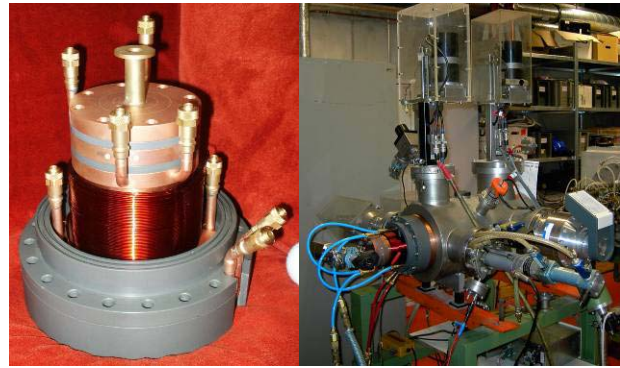


Figure 4: The ion source (left) attached to the emittance measuring system (right).

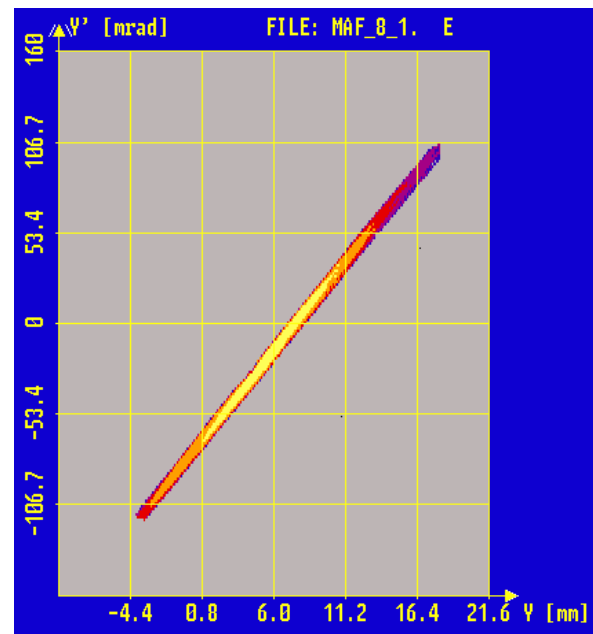


Figure 5: Measured source emittance with  $\epsilon_{\text{rms},n} = 0.022 \pi \text{ mm mrad}$ .

### THE TEST STAND

The electrostatic injection system, which is currently installed to the test bench, consists of four equally designed quadrupoles (Fig. 7) with an aperture of 25 mm and a electrode length of 100 mm. The distance between the quadrupoles is 50 mm. Due to preliminary calculations with RFQsim we expect a transmission of about 80% (Fig. 8,9) using the measured emittance shown in Fig. 5. The distance between ion source and the first quadrupole has to be kept as short as possible (5 cm), in order to avoid transversal losses. The distance between quadrupoles and RFQ entrance can be left much wider giving enough space for the steerers. The particle tracking through the RFQ-channel has been done on the basis of milling data of the electrodes, which can be fed into RFQsim cell by cell. The voltages of the quadrupole electrodes are in the order of 3 kV.

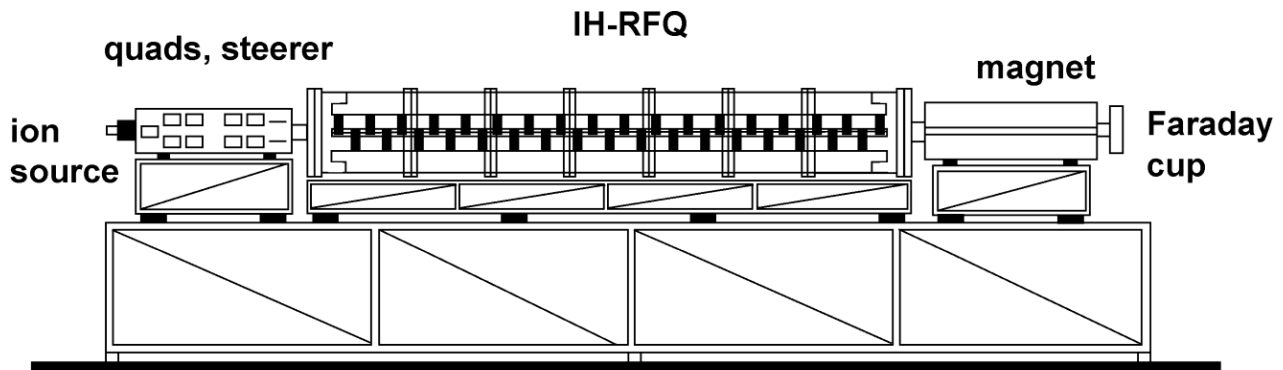


Figure 6: Scheme of the test stand.

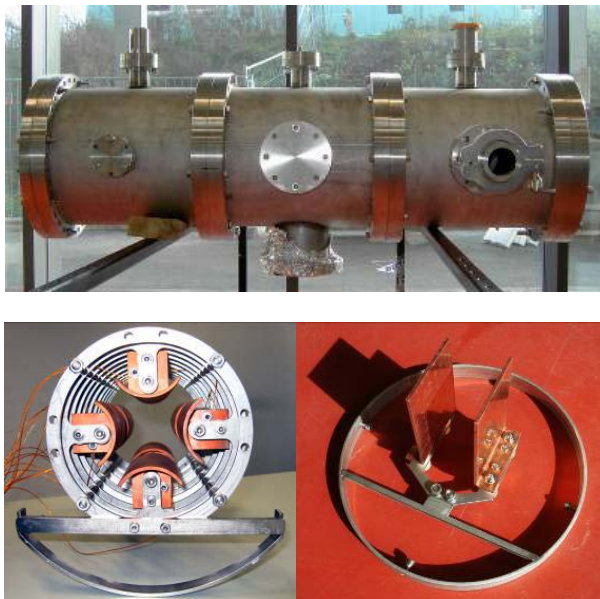


Figure 7: The LEBT tank (top), the electrostatic quadrupoles (bottom left) and one of the steerers (bottom right) forming an electrostatic injection system to match the ion source emittance to the acceptance of the RFQ.

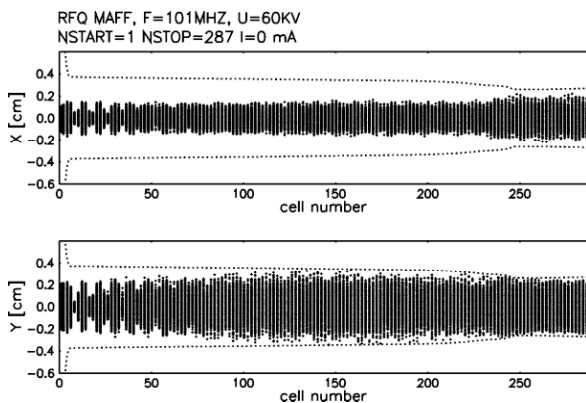


Figure 8: Transversal particle tracking with RFQsim. The measured source emittance (Fig. 4) has been used for this simulations. The over all transmission including the LEBT is about 80%.

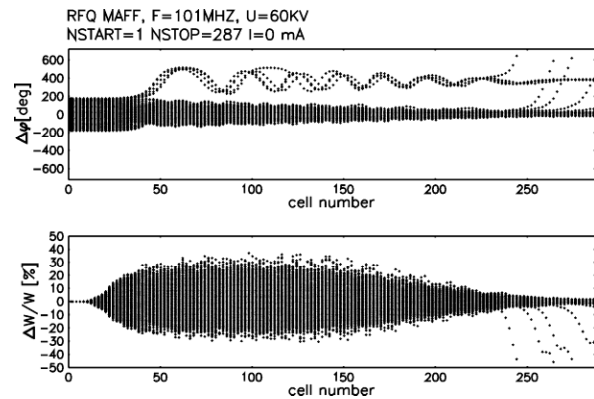


Figure 9: Longitudinal beam plot. Some particles are moving to an adjacent bucket. They are executing stable oscillations and are also accelerated to the final energy.

### CONCLUSIONS

The MAFF IH-RFQ has been assembled at the IAP in Frankfurt and is about to be tested on a dedicated test stand. The ion source has already been tested successfully; the electrostatic injection system is currently installed to the test bench. Next step will be the preparation of the RFQ for high power RF-tests.

### REFERENCES

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